LAKE HURON BEACHES

Factors Affecting Microbiological

Water Quality

In

1984

SUMMARY REPORT

MINISTRY OF THE ENVIRONMENT

Southwest Regiôn

Technical Support

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1. CONCLUSIONS

1.1 Beach Quality

During the 1984 study, the microbiological quality of the beaches at Grand Bend, Ipperwash Provincial Park and Goderich was assessed. Routine daily monitoring of these three beaches included the collection of samples at waist depth. At Grand Bend and Goderich where beach slope is greater, sampling locations were much closer to the shoreline than at Ipperwash. Analyses of these beach samples revealed that there are significant differences between the three beaches. Ipperwash tended to have the lowest concentrations of fecal bacteria at the sampling depth. Concentrations of fecal bacteria at Grand Bend and Goderich were quite similar. Goderich, however, tended to have the highest levels of fecal bacteria. At all three beaches, fecal bacteria periodically reached levels of concern. Hence, measures to reduce the loading of fecal bacteria to these beach areas are warranted.

Efforts were made to correlate beach bacterial levels with numerous factors. The best correlation appeared to be with lake roughness. It is concluded that heavy wave action is instrumental in contaminating beach waters by re-suspending the beach sediments which contain elevated concentrations of bacteria. It is of interest to note that Goderich beach, which tended to have the highest levels of fecal bacteria also was the most turbid. Ipperwash, which had the lowest levels of fecal bacteria, was the least turbid.

It is assumed that fecal bacteria entering these inshore beach areas largely settle to the lake bottom where they can survive for weeks, if not months. The beaches, because of their exposure, are frequently subject to heavy wave action causing bottom resuspension.

The loading of fecal bacteria to these beach area comes, of course, from the rivers and creeks which carry in fecal material from numerous activities on the watersheds, especially under rain events.

1.2 Bacterial Sources

Various activities were undertaken to assess the significance of possible sources of fecal bacteria. These activities included sanitary surveys of the urban centres (e.g. Grand Bend and Goderich), boat and marina surveys, point-source investigations, sampling in the agricultural areas, records of pets, seagulls and swimmers at the beach, etc. In a couple of cases, namely at Duffus Creek and the Walker Drain, obvious localized contamination was found, and corrective measures were initiated. In general, however, it is concluded that the bulk of the fecal bacterial load to the beach areas is simply a result of the combination of numerous, "diffuse" bacterial sources on the watersheds. For example, when the Ausable Watershed was monitored at numerous locations, bacterial contamination was found, to varying degrees, throughout the watershed. Similarily, study component #4 found that all of the tributaries sampled that enter the lake directly, showed varying degrees of contamination; some were quite highly contaminated.

The surveys of the creeks and rivers revealed that under conditions of rainfall and runoff, concentrations of fecal bacteria in these watercourses increase substantially. With the increase in flow and the increase in contamination, it is apparent that the bacterial load to Lake Huron increases dramatically during major rainfall events. It would generally appear that the majority of the fecal bacterial loading to the Lake Huron beaches comes from the agricultural areas.

1.3 Problem Correction

There are obviously many sources of fecal bacteria on the watersheds which drain into the beach areas. Both urban and rural sources were apparent from this study.

With regard to the urban sources, some corrective measures have already been initiated (e.g. Duffus Creek), and others must follow.

Since it is apparent, however, that agricultural sources are more significant than urban sources, beach improvements will depend largely on reducing these agricultural sources. The watersheds draining into the study area have sizeable livestock populations. Livestock manure, which is rich in fecal bacteria, has been shown in other studies (e.g. Pittock) to gain access to waterways through a number of routes. The primary routes are believed to be as follows:

1. barnyard surface runoff during rainfall
2. barnyard manure seepage into field-tile systems
3. cattle access to creeks and rivers
4. erosion of manure-spread fields
5. manure spills

Since much of the manure that enters watercourses would appear to enter as a result of normal farm practice, it is apparent that problem correction will prove difficult. Nevertheless, improvements to Lake Huron beach quality will depend largely on improved manure management on the watersheds of the Ausable, Maitland and other watercourses.

The Ministry of Environment has already been working with the Ministry of Agriculture and Food, the Ausable-Bayfield Conservation Authority, and the Huron County Soil Conservation District, in an effort to bring about improved soil and manure management.

1.4 1985 Plans

The Ministry of the Environment intends to carry out further work, during 1985, in an effort to better understand the problem of elevated fecal bacterial levels at some of the major Lake Huron beaches. Also, efforts will continue, and perhaps increase, in the field of the management of fecal waste. In particular, increasing attention must be given to soil and manure management.

2. INTRODUCTION

The beaches along the Lake Huron shoreline are amongst the most popular in southern Ontario, drawing vacationers from across Ontario and the Northern United States. The main resort areas are places such as Port Franks, Grand Bend, Bayfield, Goderich, Bruce Beach, Kincardine, Inverhuron, Port Elgin, Southampton and Sauble Beach. Tourism is a multi-million dollar industry in this area.

In 1983, a number of beaches along the Lake Huron shoreline were posted because of elevated bacterial concentrations. Some survey work was initiated during the summer of 1983 at Grand Bend to obtain preliminary information on bacterial sources. However, few conclusions could be reached, and it was decided to carry out a more detailed investigation during 1984. This report outlines the summary results of the 1984 investigation.

3. STUDY SCOPE AND METHODOLOGY

The complexities of bacterial contamination are reported in the literature, and were well-known by the project leaders. At any one beach, numerous factors can interact to give widely fluctuating bacterial levels not only from one day to the next, but from one hour to the next. Influencing factors can include river discharges, storm sewers, wastewater discharges, agricultural drainage, birds, pets, swimmers, sunlight, lake roughness, turbidity, etc.

The approach used in the 1984 study was basically to establish the bacterial levels of the beaches along the Lake Huron shoreline and other key areas of interest. In addition, climatological and physical information was recorded to determine if correlations could be made with the bacterial levels.

A Ministry of the Environment mobile laboratory was transported to Grand Bend to serve as a microbiological laboratory and field headquarters. A total of eight students were hired to carry out the day-to-day field and laboratory activities. Program direction and supervision was looked after by Ministry staff from the London office.

The basic program commenced on June 13, and ended 13 weeks later on August 24. In total, over 10,000 microbiological tests were completed at the mobile lab, and an additional 1000 at the London laboratory. Including all of the observations and measurements, in excess of 25,000 data pieces were collected. Most of the data were entered on computer for ease of data handling and manipulation.

For study organization, the survey was divided into two major sections. The first section, known as component 1, simply involved daily monitoring of the three beaches - Grand Bend, Ipperwash Park, and Goderich.

At each of these three beaches, three beach locations were established, at a water depth of 1 - 1.5 m, for daily sampling. In addition, the major rivers in the area (Ausable, Bayfield, Maitland) were monitored daily. Component #1 included daily bacteriological sampling of 15 locations. In addition to the bacteriological sampling, other measurements were made (e.g. turbidity) and numerous observations were recorded (e.g. number of swimmers).

The second area of the study involved shorter-term, more specific work. This second area was divided into components 2 - 14. The following provides some information on the nature of each component:

#2 - Sauble Beach Survey - Sauble Beach could not be included in component #1 because of distance. Nevertheless, two 3-day field trips were taken to Sauble Beach in a preliminary effort to assess bacterial contamination.

#3 - Ausable River - On several dates, 32 locations throughout the Ausable watershed were sampled in an effort to gain some understanding of bacterial sources to the area.

#4 - Small Creeks - In addition to the major rivers that enter Lake Huron between Ipperwash and Goderich, numerous small creeks enter this area and have the potential to affect beach quality. On several dates, 16 of these small creeks or drains were sampled.

#5 - Beach Quality With Regard to Time of Day and Distance from Shore - On selected days, intensive sampling was carried out at Grand Bend and Ipperwash in an effort to determine the bacteriological impact of swimmers and the bacterial variability with water depth and distance from shore.

#6 - Dispersion of the Ausable and Maitland Rivers into Lake Huron - Because of the size of these rivers and their vicinity to the beaches at Grand Bend and Goderich, their dispersion patterns were assesed to evaluate their potential to move onto the beaches.

#7 - Sanitary Surveys at Grand Bend - Grand Bend does have a modern sewerage servicing system, nevertheless, periodic sanitary surveys were carried out to evaluate the degree of contamination in various storm drainage systems.

#8 - Sanitary Surveys at Goderich - Similarily, sanitary surveys were carried out at Goderich.

#9 - Inventory of Sewage Bypass - Operators of sewage systems on the watersheds draining into the Ipperwash to Goderich area were asked to maintain records of sewage bypasses.

#10 - Contamination of Walker Drain and Duffus Creek - Excessively high bacterial levels were found in these two small watercourses in the area of Ipperwash - Grand Bend. Corrective measures were initiated.

#11 - Boat Inspections - Numerous boats were inspected to ensure adequate holding facilities.

#12 - Impact of Marina Areas - Work was done upstream and downstream of marina areas to evaluate the bacteriological impact of high densities of recreational boats.

#13 - Specialized Microbiology Work - Various types of specialized microbiology work was done in an effort to better understand bacterial sources.

#14 - Bacterial Contamination of Beach Sediments - It is known that sediments can harbour high concentrations of bacteria over extended periods. Numerous sediment analyses were, therefore, carried out.

These 14 component studies involved numerous field and laboratory techniques and procedures. While much of the methodology followed standard Ministry procedure, some procedures were developed specifically for this study. This report does not include an outline of the methodology used. However, all non-standard methodology has been documented, and is on file at the Ministry of the Environment.

With regard to the general reporting and interpretation of the data, it should be pointed out that this report is a generalized summary report. The authors have reviewed many data relationships which do not appear in this report. It is hoped that time will allow for a more detailed assessment and report of certain parts of the study. However, all data not presented in this report is available in summarized component format from the London Regional Office of the Ministry of the Environment.

4. FACTORS AFFECTING MICROBIOLOGICAL QUALITY OF BEACHES

The Lake Huron beaches can potentially be affected by numerous bacterial sources, including:

a) urban storm drainage

b) poorly functioning sewage systems

c) agricultural drainage

d) pets and wildlife

e) boats

f) swimmers

Sorting out the relative significance of all the potential sources is aggravated by the influence of climate. Rainfall events can flush agricultural and urban drains containing high bacterial levels. Winds can result in the resuspension of bacterial-rich bottom sediments. Wind direction can be important, as it can direct contaminated river water onto beaches. Sunny days can also be important, as ultraviolet light can reduce bacterial levels. Water temperature can affect the survival rates of various types of bacteria, and affect beach usage.

With all of these factors involved, data interpretation is difficult.

5. DISCUSSION OF DATA

The large majority of data generated during this study are not included in this summary report. All data is available from the London Regional Office of the Ministry of the Environment. It is in an appendices-type format that was not included in this summary because of its large volume. The Tables and Figures hopefully allow the reader to envisage the relative order of the concentrations of bacteria found at the numerous sampling sites.

5.1 Component 1 - Routine Sampling

Component 1 simply involved the daily measurements and observations at the 15 sampling locations shown in Figure 1. This allowed the formation of a strong data base to determine the variation with time at these locations.

5.1.1 Grand Bend

Grand Bend beach is illustrated in plate #1. The beach slope, beyond the water line, is about 30% until 40 meters out where the first sand bars exist.

The Grand Bend beach is bordered inland by the community of Grand Bend, which is largely serviced by a modern sewerage system. Immediately to the south of the beach is the entrance of the "Old" Ausable River which carries the flow from the Parkhill Creek portion of the watershed.

The daily sampling program in the Grand Bend area included samples from near the mouth of the "Old" Ausable river (upstream of the village) since it was believed that the River could be a significant source of bacteria to the beach. This section of the report, therefore, will interpret data collected from Grand Bend beach and the "Old" Ausable.

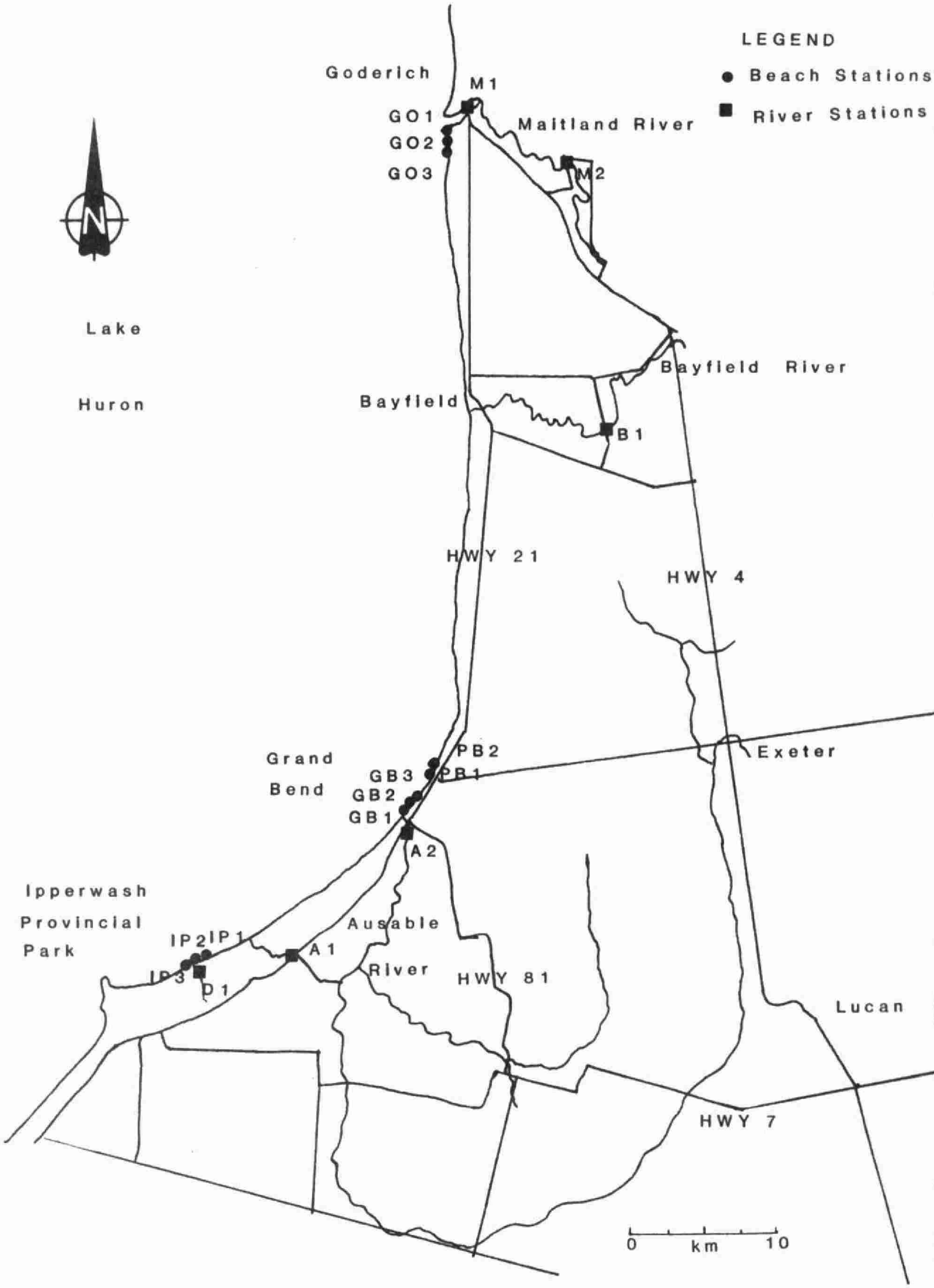


Figure 1. Location of the routine monitoring stations during the beach study of 1984.

Plate 1. View of Grand Bend Beach

Plate 2. Aerial View of Grand Bend Showing Dispersion of the Ausable River into Lake Huron

Figure 2 illustrates average daily concentrations of fecal coliform bacteria at the Grand Bend beach, along with some of the factors that seem to influence the bacterial levels (rainfall and lake roughness). Figure 3 illustrates the daily beach concentrations of fecal Streptococci and Enterococci. Fecal coliform levels in the "Old" Ausable River, as well as rainfall are illustrated in Figure 4.

Data interpretation proved difficult. Nevertheless, a careful review of the data (not included), along with the interpretations of Figures 2 - 4, enable us to make the following observations:

1. Bacterial concentrations in the beach water and in the river water fluctuated greatly from one day to the next. On some days, levels in excess of the criteria were found.

2. 37% of the samples from the beach contained the pathogenic bacterium, Pseudomonas aeruginosa.

3. Concentrations of fecal coliforms in the "Old" Ausable correlated well with rainfall events. Major rainfalls resulted in high river concentrations.

4. Some of the peaks in fecal coliform levels in the beach water appear to correlate with rainfall. For example, the highest concentration corresponded with the largest rainfall on day 5.

5. Wind direction seemed to be important. For example, during the major rainfall events of days 5 and 24, south winds were observed to be "blowing" the turbid river water northward onto the beach (see Plate 2).

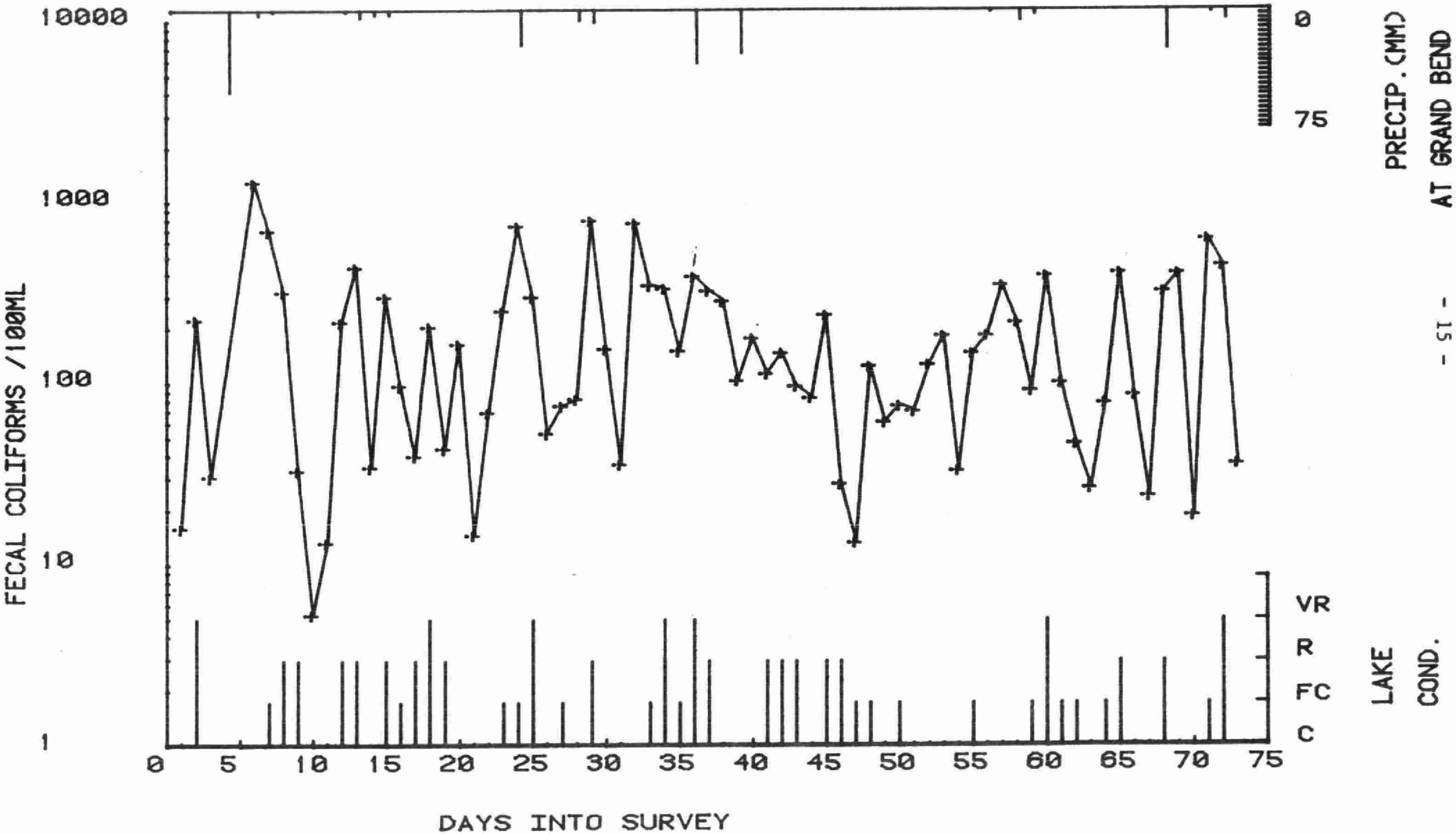


Figure 2. Levels of fecal coliform bacteria at Grand Bend beach. Each data point represents the mean of the 3 stations collected. Lake condition (VR - very rough, R - rough, FC - fairly calm, C - calm).

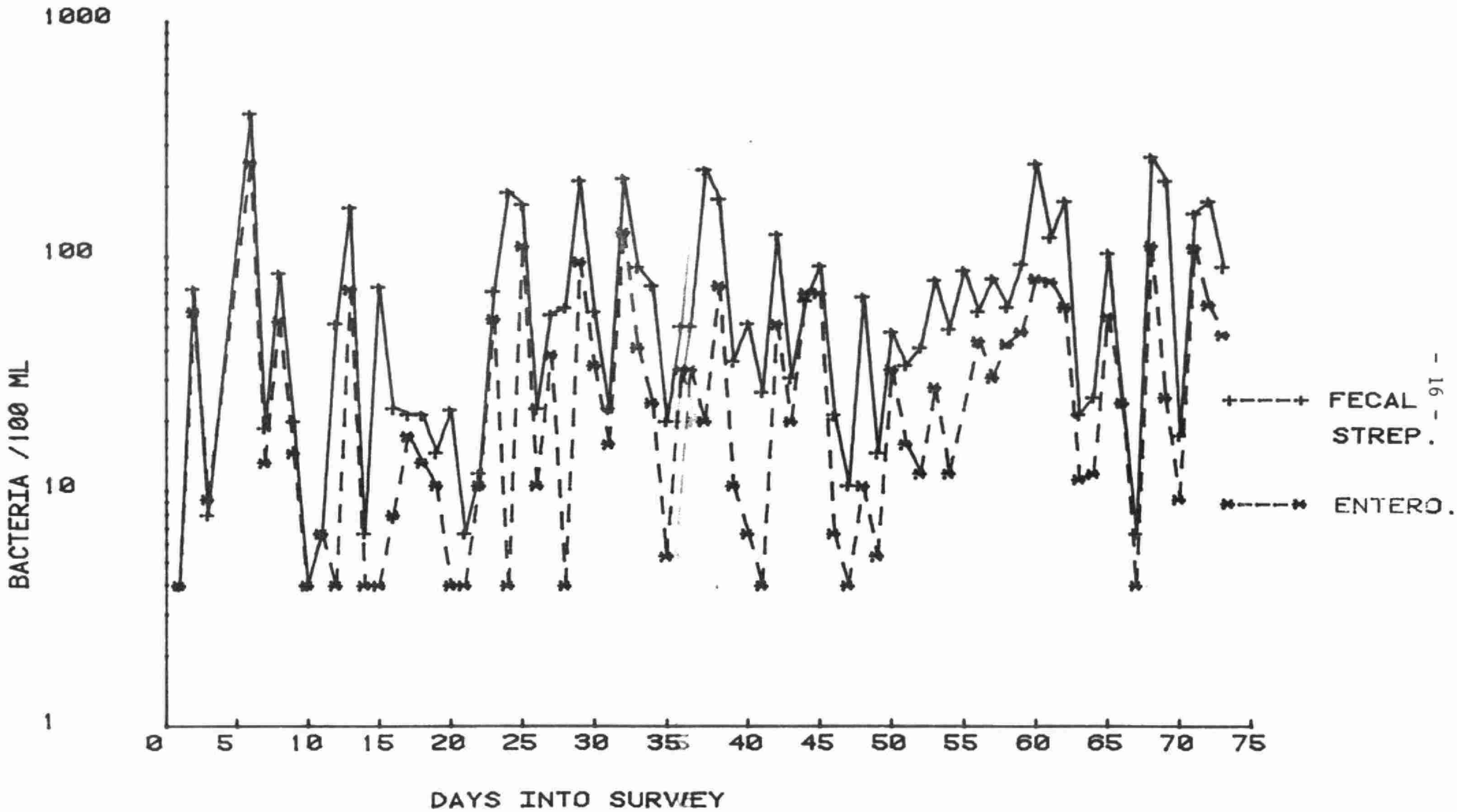


Figure 3. Levels of fecal streptococci and enterrococci at Grand Bend beach. Each data point represents the mean of the 3 stations collected.

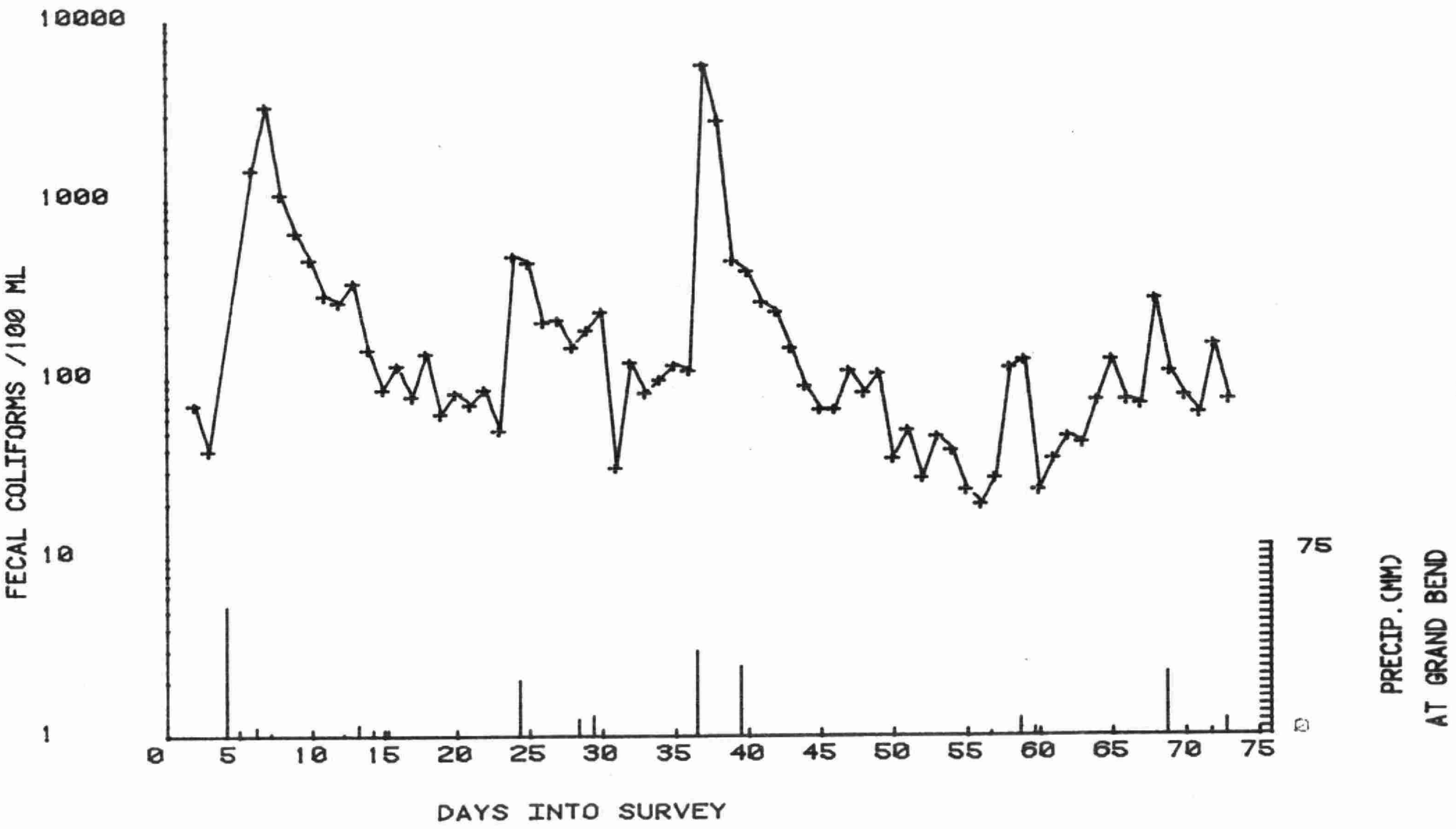


Figure 4. Levels of fecal coliform bacteria at stationA2 near the mouth of the "Old" Ausable River.

6. Bacterial levels on the beach appeared to correlate closely with roughness of the beach waters. On rough days when the beach waters were turbid (sometimes greater than 100 FTU), bacterial levels tended to be elevated. Under calm-water conditions, when beach waters were clear (often less than 10 FTU), bacterial levels were normally low. The bacterial-rich beach sediments can have a substantial impact on the overlying beach water.

7. The disinfecting affect of sunlight may have been significant. At times when bacterial levels were decreasing, daily hours of direct sunlight tended to be greater.

8. From this component, there would appear to be little or no apparent correlation of beach bacterial levels with factors such as numbers of swimmers or numbers of seagulls. However, any relationship could have been masked by other factors mentioned above.

5.1.2 Ipperwash

Ipperwash Beach (Plate #3) is by far the shallowest of the three beaches that were studied intensively. The slope from the waterline out is only about 3% to a distance of some 50 m where the water reaches a depth of 1.3 m. Beyond this distance, several sand bars exist.

Ipperwash Beach also differs from the beaches at Grand Bend and Goderich in the sense that there are no major rivers discharging near the beach. The mouth of "The Cut", which carries most of the flow from the Ausable watershed, is several kilometers north of Ipperwash Beach. There is a small creek, nevertheless (Duffus Creek) which discharges onto the beach. Duffus Creek was sampled daily as part of this routine monitoring program.

Plate 3. View of Ipperwash
Provincial Park Beach

Plate 4. Aerial View of Ipperwash
Provincial Park showing
dispersion of Duffus Creek
into Lake Huron

Ipperwash Beach also differs from Grand Bend and Goderich Beaches, by the absence of an urban community bordering the beach.

Figure 5 illustrates fecal coliform levels on the beach, as well as precipitation and lake roughness. Figure 6 illustrates the concentrations of fecal Streptococci and Enterococci. Figure 7 illustrates the concentrations of fecal coliforms in Duffus Creek near the mouth. A review of the data in these figures, along with a study of the data (unreported), enables us to make the following observations:

1. Bacterial levels in beach water fluctuated greatly from one day to the next, similar to the fluctuations found at Grand Bend. Daily maxima and minima were similar between Ipperwash and Grand Bend. In general, however, average fecal coliform concentrations were lower at Ipperwash.

2. 22% of the samples from the beach contained the pathogenic bacterium, Pseudomonas aeruginosa.

3. There would appear to be a correlation between major rainfall events, and fecal coliform levels in the beach water (figure 5).

4. Beach bacterial levels appear to correlate with lake roughness. On rough days, bacterial levels tended to be higher, probably as a result of suspending bacterial-rich sediments.

5. Concentrations of fecal coliform bacteria in Duffus Creek were typically very high. The reason for these high concentrations will be discussed in section 5.10. Duffus Creek, because of its small size, however, would appear to have a very localized impact on Ipperwash

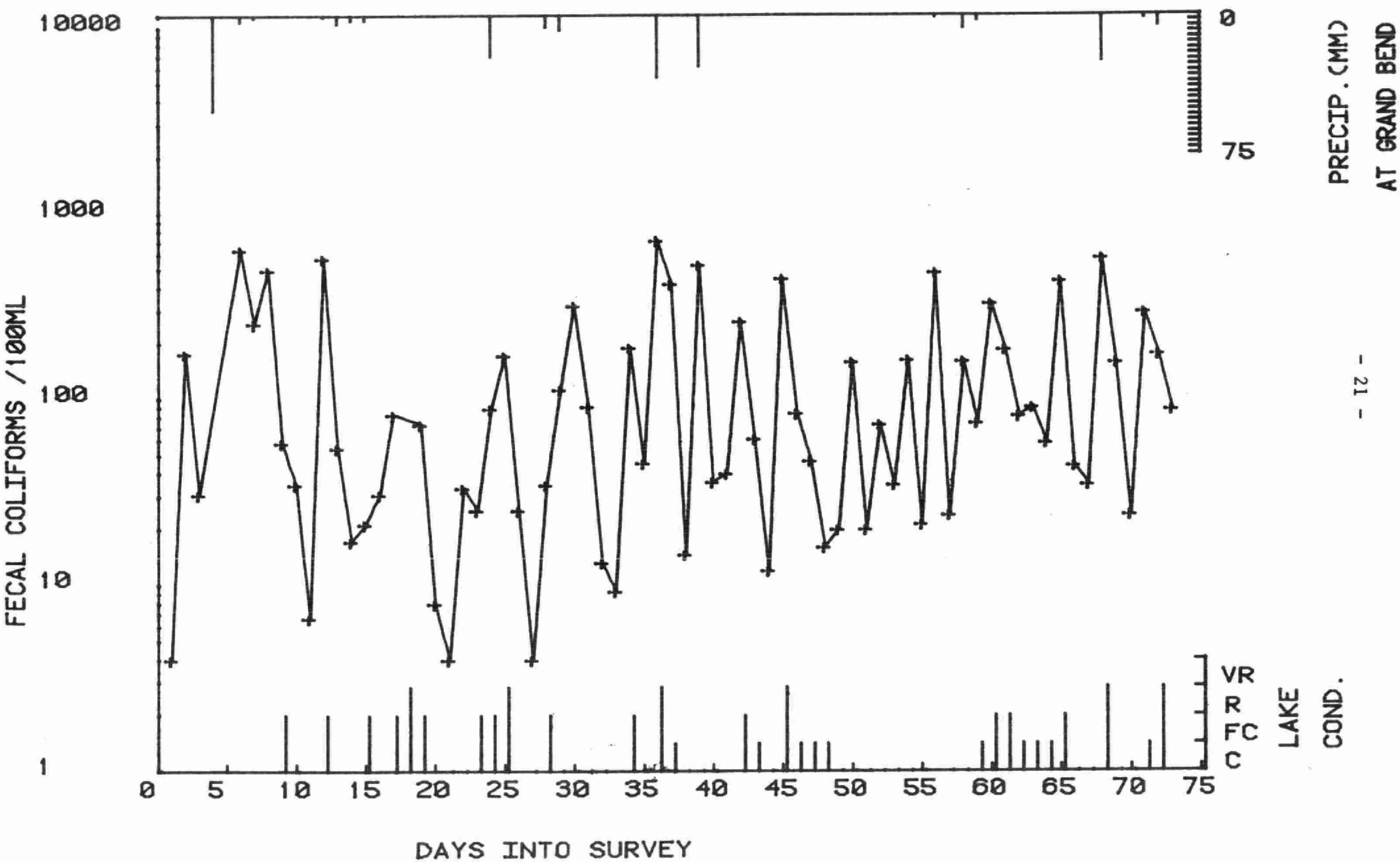


Figure 5. Levels of fecal coliform bacteria at Ipperwash Provincial Park beach. Each data point represents the mean of the 3 stations collected. Lake condition (VR - very rough, R - rough, FC - fairly calm, C - calm).

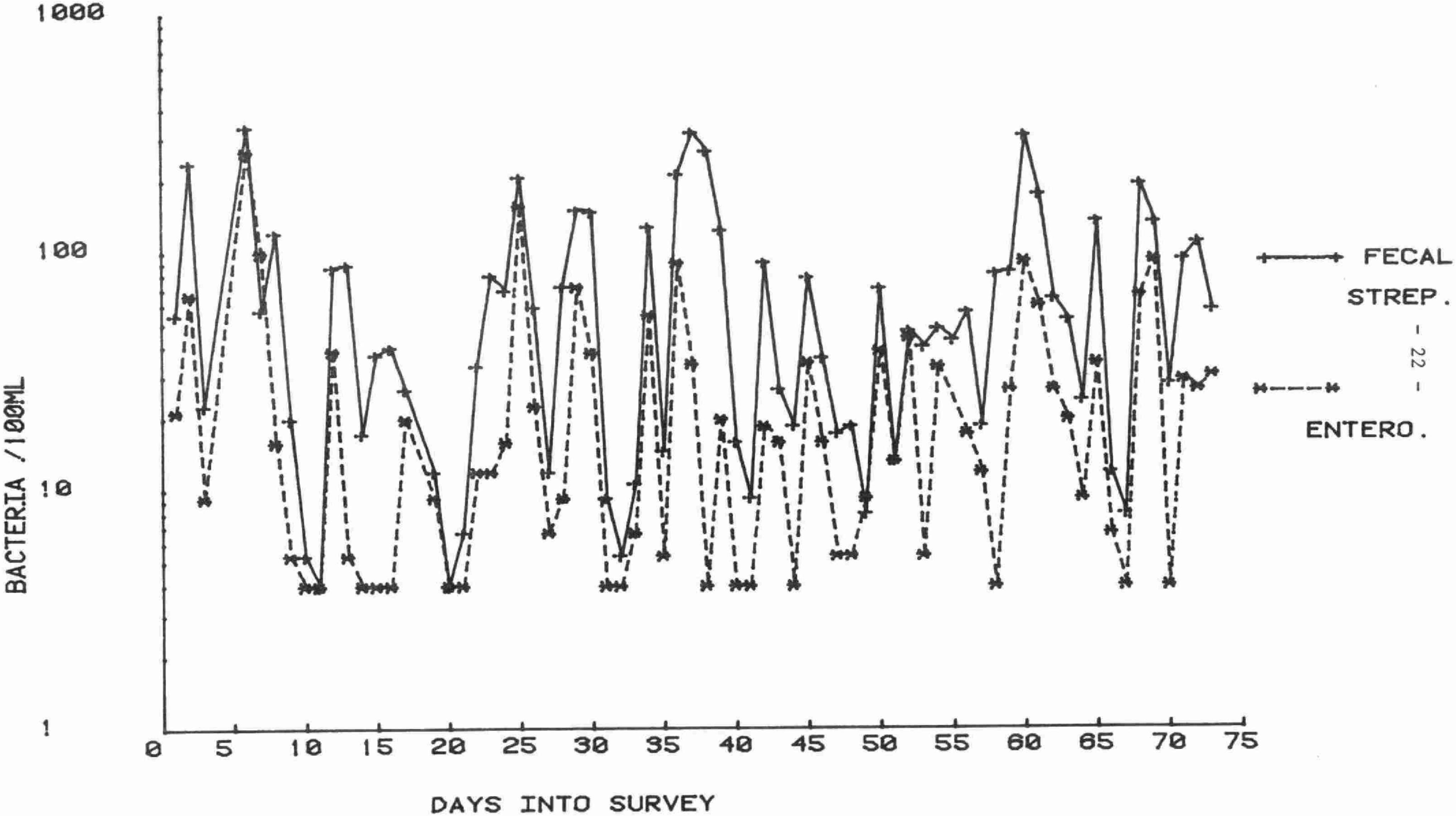


Figure 6. Levels of fecal streptococci and enterococci at Ipperwash Provincial Park beach. Each data point represents the mean of the 3 stations collected.

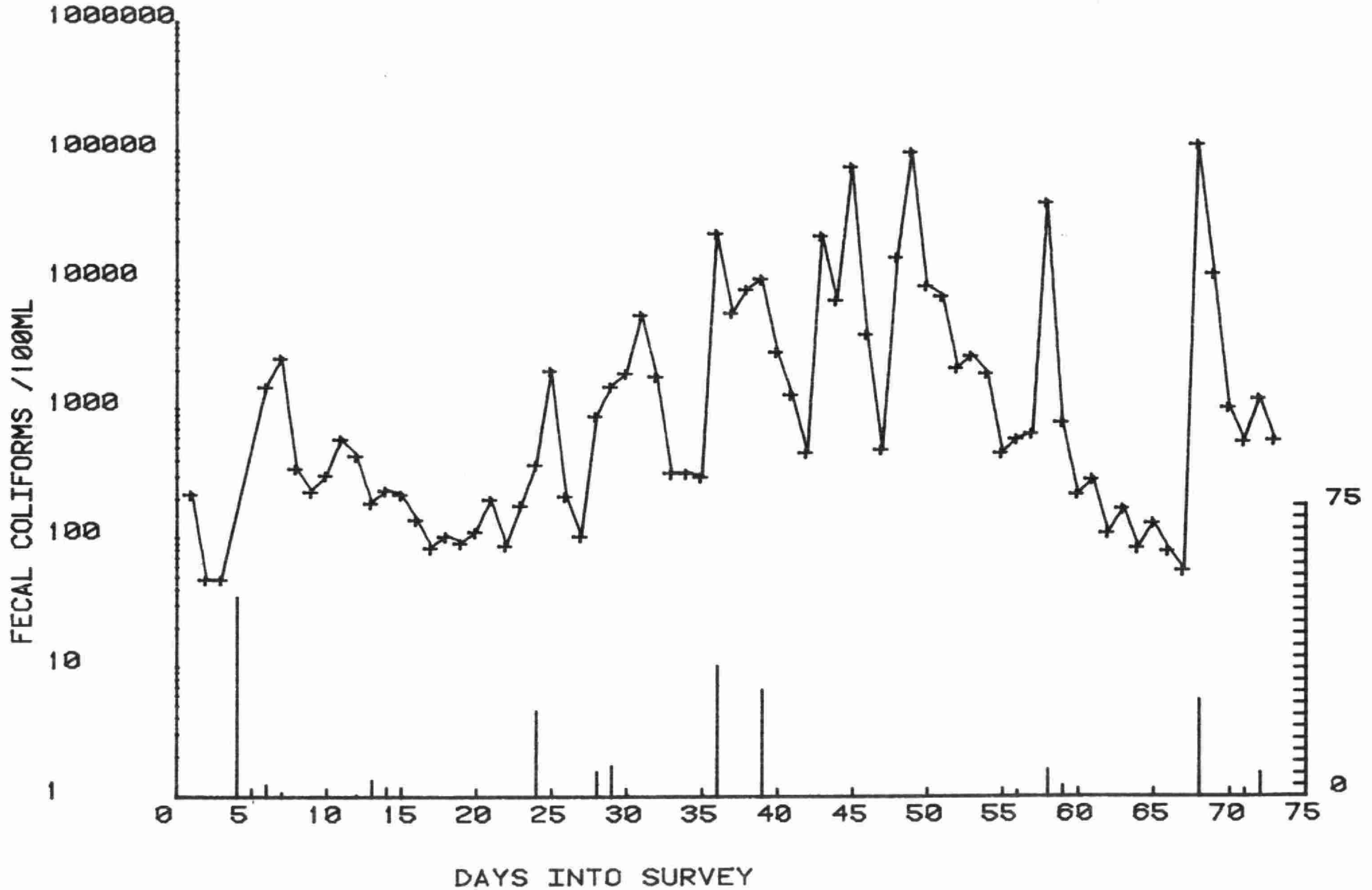


Figure 7. Levels of fecal coliform bacteria at station D1 near the mouth of Duffus Creek.

Beach (see Plate 4). Data from the three beach monitoring stations in general did not show the impact of Duffus Creek, probably because of the distance separating the creek mouth from the beach monitoring stations. However, station 3, located near Duffus Creek, did show elevated bacterial levels following rainfall events.

5.1.3 Goderich

Goderich Beach (plate #5) is located in the Town of Goderich, a short distance south of the Maitland River mouth. The beach slope (40%) is greater than the slope at Grand Bend, and of course much greater than the slope at Ipperwash.

The beach is bordered by St. Christopher's Beach to the south, by the Town of Goderich to the east, and by Goderich Harbour and the Maitland River to the north.

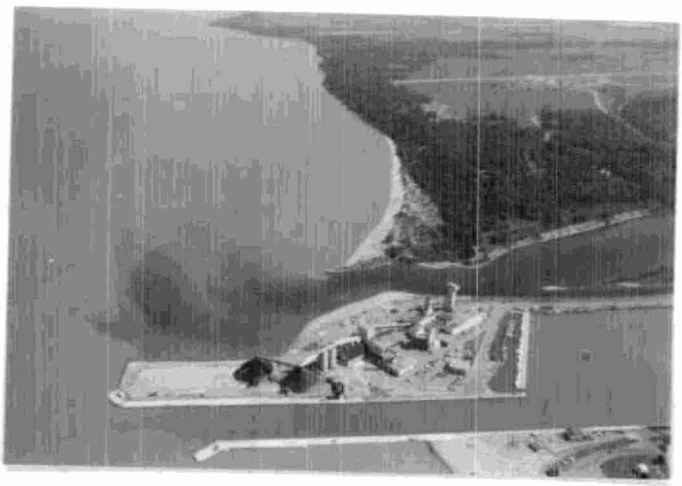
At the beginning of the study, it was decided that the Maitland River was close enough to potentially impact the beach (see Plate #6). Hence, the mouth of the Maitland was included in the daily monitoring program.

Unlike the situation at Grand Bend and Ipperwash, there is a continuously-discharging sewage treatment plant outfall in the vicinity of Goderich Beach (0.5 - 1 km south). This effluent was monitored as part of the study, with the results presented in section 5.8.

A statistical review of the bacteriological data from the three beach monitoring stations revealed that it was not possible to group all three sets of data for purposes of presentation and interpretation. Station #3 had better water quality than 1 and 2. Hence, in Figures 8, 9 and 10, there are two plots rather than one. The fecal coliform data from the mouth of the Maitland River are presented in Figure 11.

Plate 5. View of Goderich Beach

Plate 6. Aerial View of Goderich Harbour Showing Dispersion of the Maitland River into Lake Huron



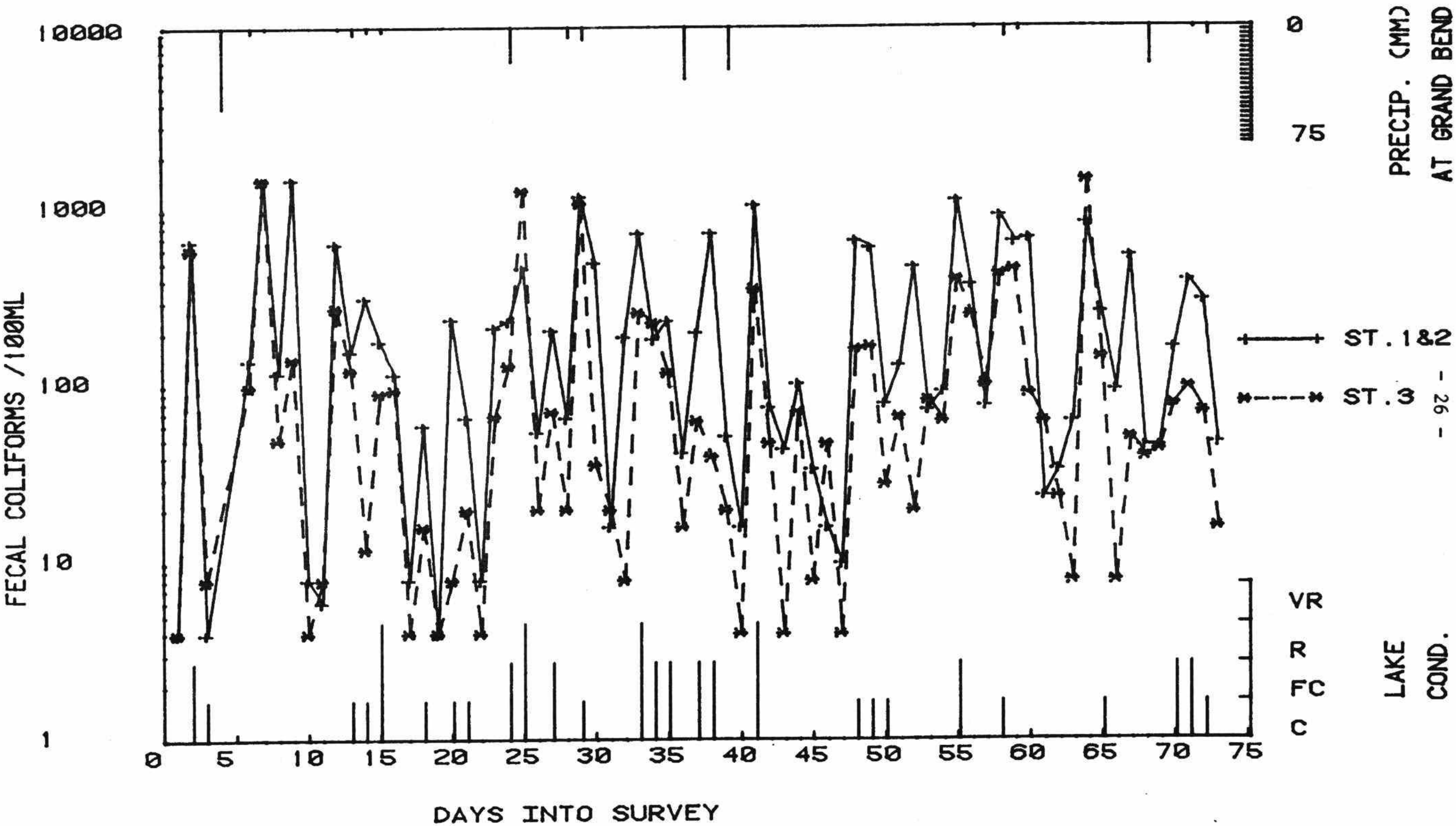


Figure 8. Levels of fecal coliform bacteria at Goderich beach. Lake condition (VR - very rough, R - rough, FC - fairly calm, C - calm).

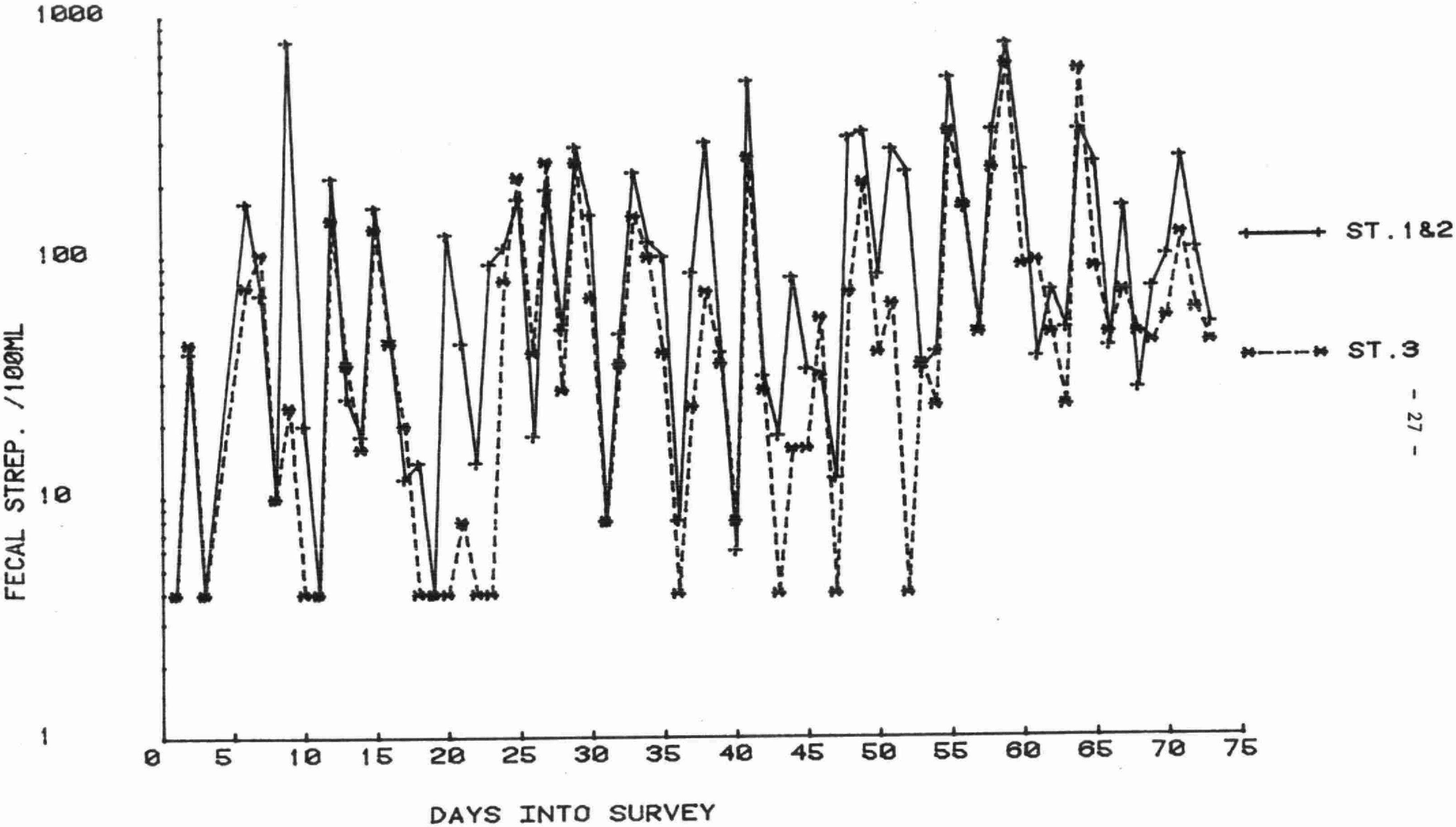


Figure 9. Levels of fecal streptococci at Goderich beach.

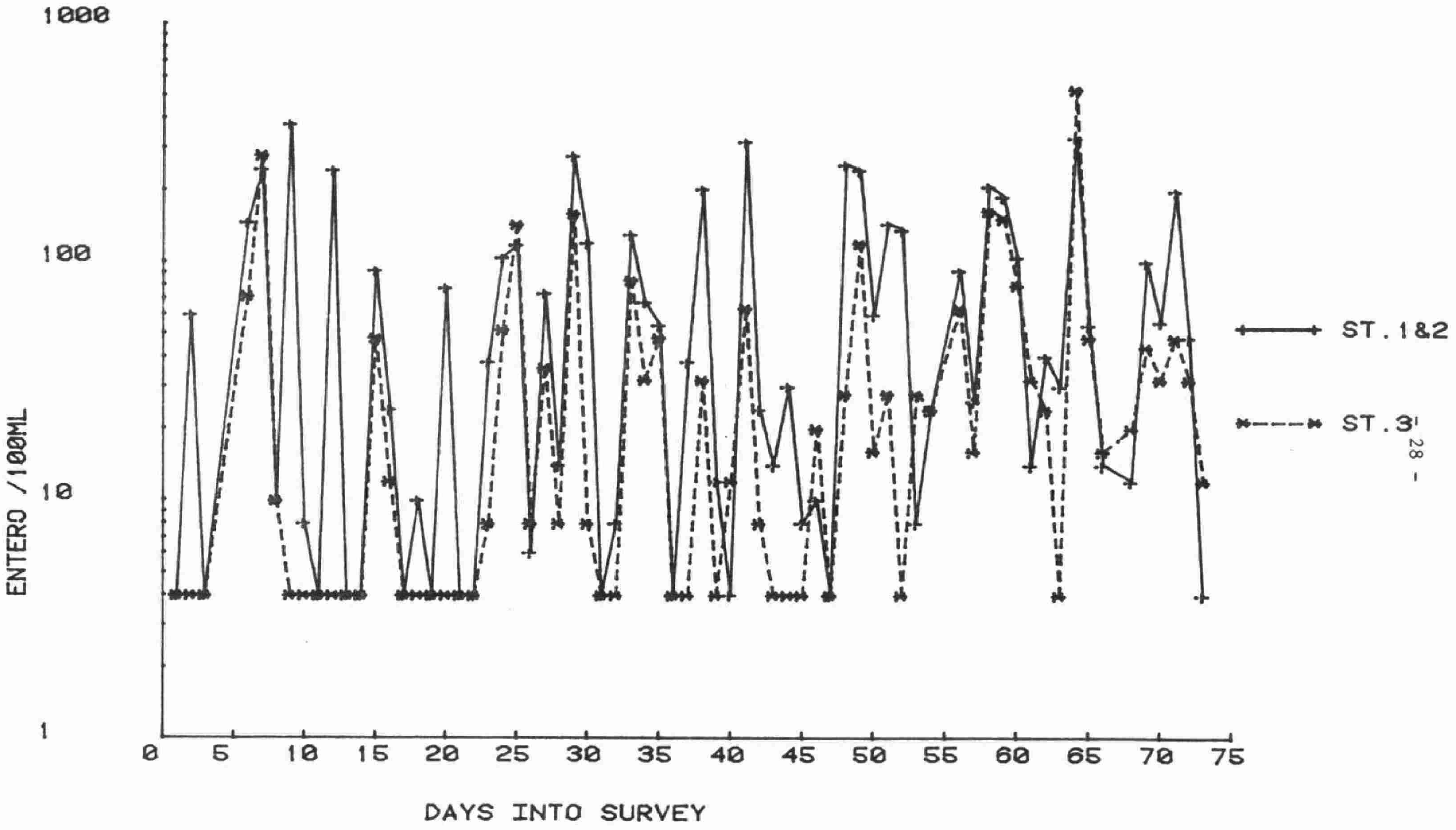


Figure 10. Levels of enterococci at Goderich beach.

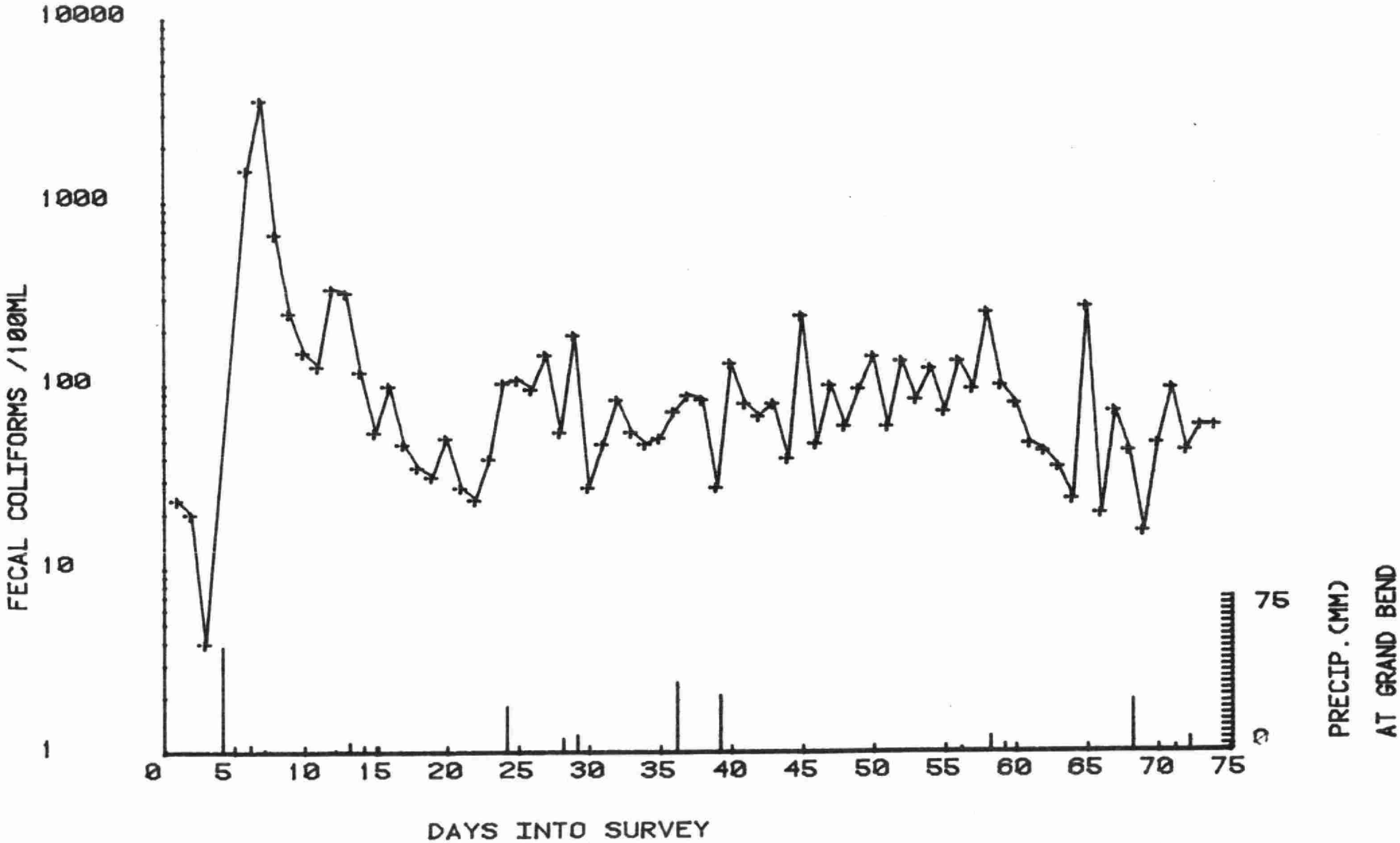


Figure 11. Levels of fecal coliform bacteria at station M1 near the mouth of the Maitland River.

A careful review of Figures 8 to 11, along with a review of the data (unreported) allows us to make the following observations:

1. Of the three beaches studied intensively, the greatest bacterial fluctuations were found at Goderich Beach.

2. Nineteen percent of the samples from Goderich Beach contained the pathogenic bacterium, Pseudomonas aeruginosa.

3. It is difficult to assess the relationship of rainfall to bacterial levels at Goderich Beach and in the Maitland River. Figures 8 and 11 illustrate the rainfall recorded at Grand Bend. Rainfall at Goderich was likely somewhat different.

4. Bacterial levels appear to correlate well with lake roughness. On rough days, bacterial levels tended to be higher, probably a result of suspending bacterial-rich sediments.

5. Fecal coliform levels in the Maitland River were not greatly different from the levels found in the "Old Ausable" and "The Cut". For some reason, however, concentrations during the last month did not decrease in the Maitland the way they did in the other two rivers. With the existing data base, it is difficult to assess the impact of the Maitland River on beach water quality.

6. Study component 1 did not provide evidence of the Goderich sewage treatment plant affecting Goderich Beach.

5.2 Component 2 - Sauble Beach Survey

Sauble Beach was the fourth major Lake Huron beach sampled as part of the study. Sauble Beach has a very shallow slope, similar to Ipperwash Beach. Waist depth is 30 - 50 m offshore.

Sauble Beach is bordered on the north by the Sauble River, and to the east by the community of Sauble Beach. Sewage servicing at Sauble Beach consists of individual septic tank systems. Previous studies of the Ministry of the Environment suggest that in general, these individual sub-surface systems result in little, if any, contamination of groundwater or the beach.

Because of the distance between Sauble Beach and the mobile laboratory at Grand Bend, sampling at Sauble Beach was very sparce relative to the sampling at Grand Bend, etc. Two field trips were taken to Sauble. On the first field trip (July 11-12), 4 samples on average were collected at each sampling site. The first sampling was under dry conditions, and the last three during or after low to moderate rainfall (i.e. "wet" conditions). On the second field trip (August 15-17), generally two samples per location were collected, both under dry conditions.

At Sauble Beach, there are numerous small rivulets formed from storm drainage which pass over the sandy beach into the lake. Many of these have intermittent flow. As these rivulets were considered a potential bacterial source to the beach water, they were sampled. Beach waters were also sampled at numerous locations, each location being offshore from a rivulet. In addition, samples were also collected from the Sauble River and from drains entering the Sauble. Figure 12 illustrates the sampling locations. Some data are outlined in Figure 13 and Table 1.

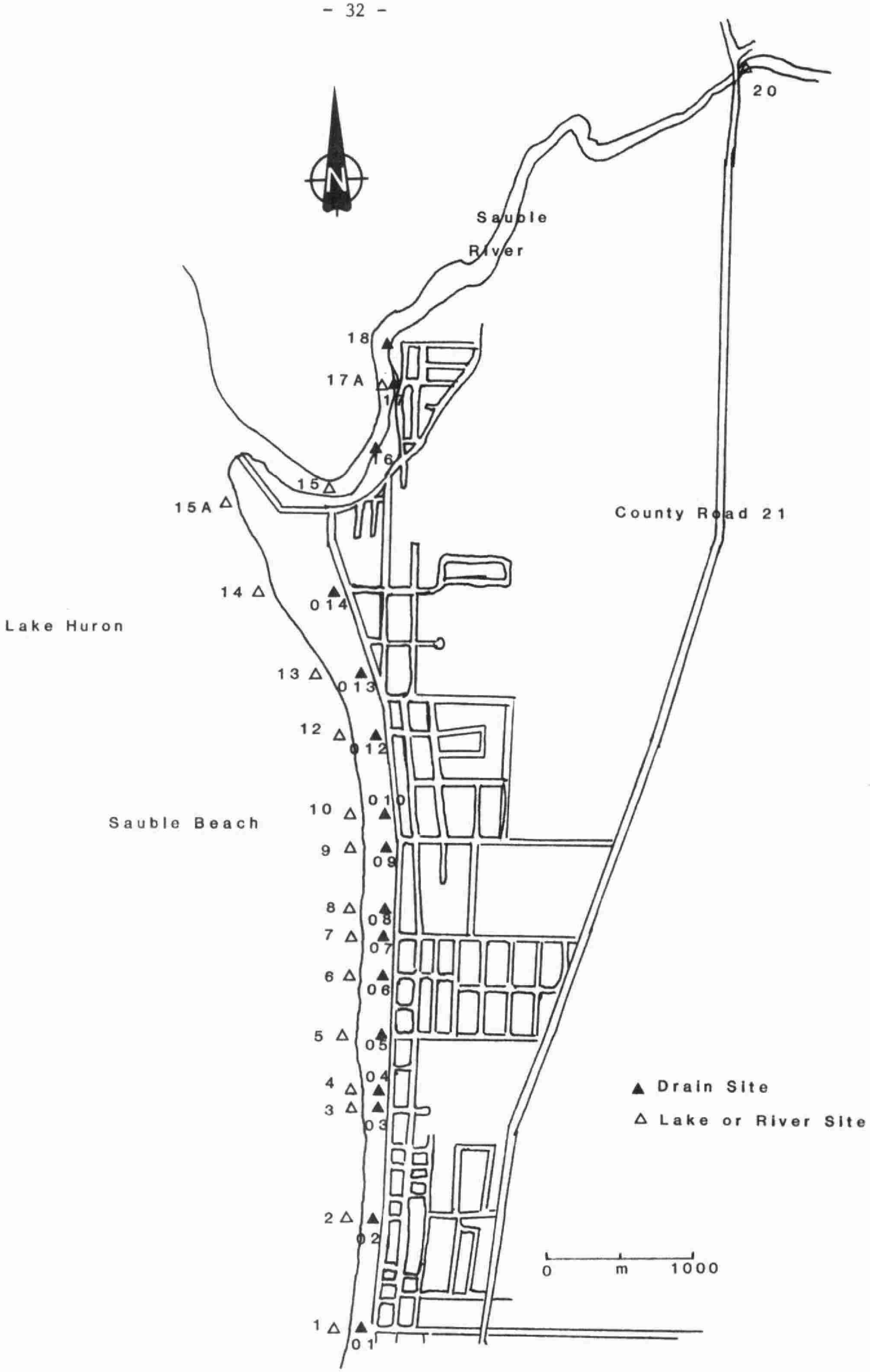
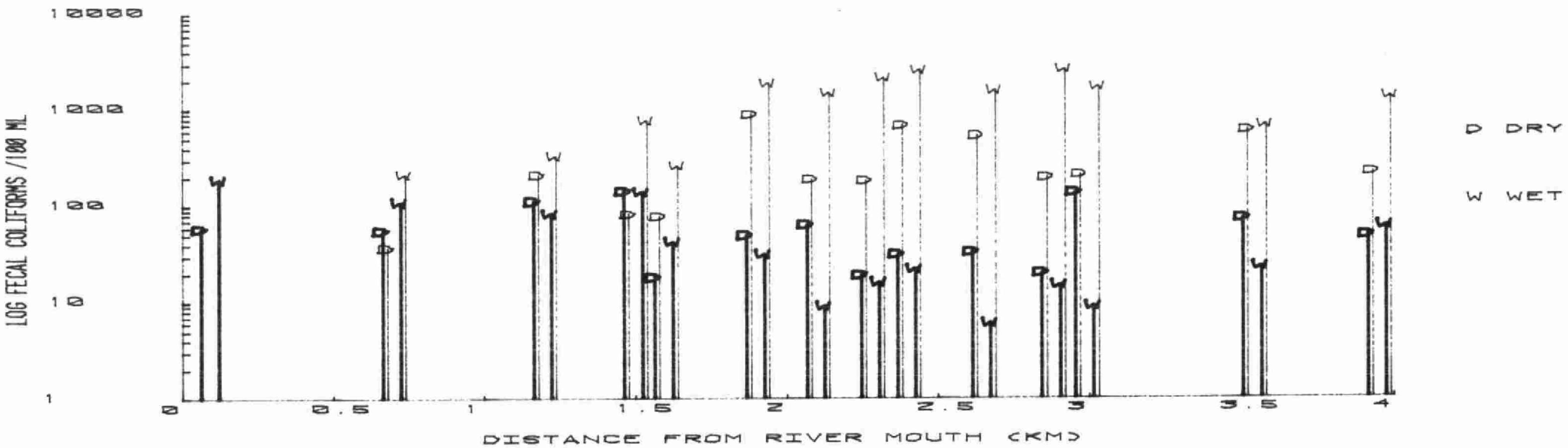


Figure 12. Sampling locations at Sauble Beach.



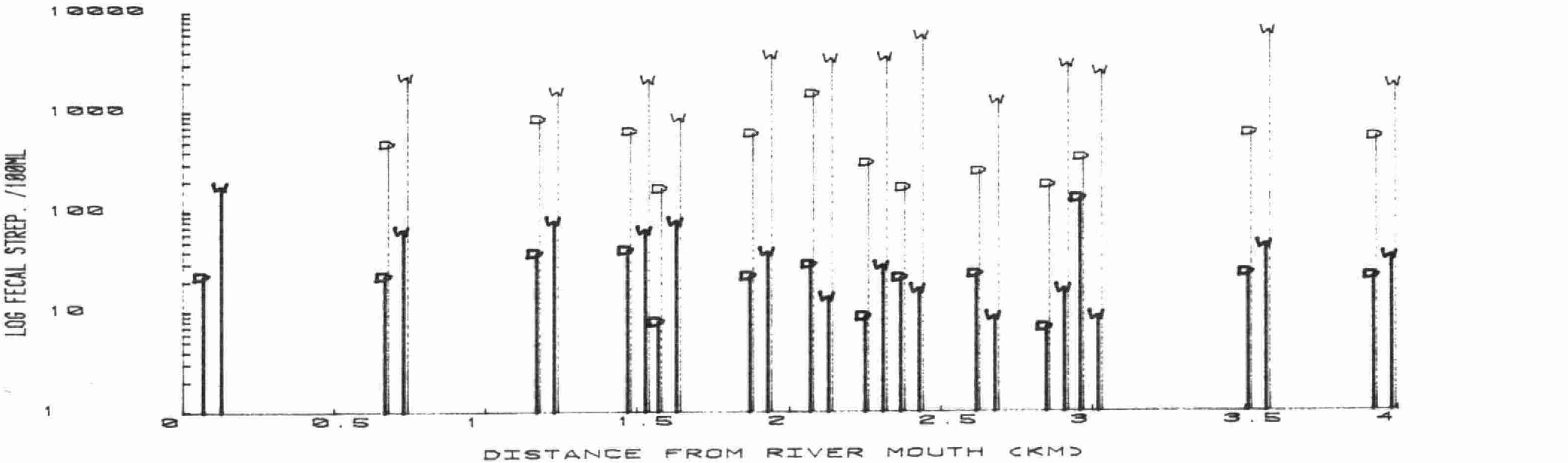


Figure 13. Levels of fecal coliform and fecal streptococci at the beach and drain stations at Sauble Beach (heavy lines are lake stations while thin lines are drain stations).

Table 1. Geometric means of fecal indicator bacteria in storm drainage and the Sauble River during the Sauble Beach study.

		FECAL COLIFORMS		FECAL STREPTOCOCCI	
		(numbers - bacteria per 100 mL)			
STATION NUMBER	SITE DESCRIPTION	Weather Condition DRY	WET	Weather Condition DRY	WET
15A	Beach at river mouth	56	208	23	184
16	Drain into River	79,359	1,500	1,096	1,054
17	Drain into River	20,399	917	585	1,189
17A	River	60	373	79	194
18	Drain into River	12,346	7,339	532	785
19	Control Site up River	12	L4	5	L4
20	River	21	93	21	82
21	River	98	267	17	119

A review of the Sauble Beach study enables us to conclude the following:

1. There is insufficient sampling to compare the general microbiological quality of Sauble Beach with the beaches at Goderich, Grand Bend and Ipperwash.

2. Most of the rivulets passing over the beach had elevated levels of fecal coliform and fecal Streptococci bacteria, especially during and after the rainfall event.

3. The three drains that discharge to the Sauble river (16, 17, 18) all had high levels of fecal coliform and fecal Streptococci bacteria during the "dry" sampling periods.

5.3 Component 3 - Ausable River

As part of the overall survey, samples were collected throughout the Ausable watershed in order to gain some understanding of bacterial sources to the river. Figure 14 illustrates the 32 sampling locations. Numbers of samples per station generally varied from a minimum of 3-4, to a maximum of 11. Approximately half the sampling runs were in rainy periods.

The data reveal that all parts of the watershed sampled had some degree of fecal contamination. It is significant to note, that only 6% of the watershed samples had fecal coliform levels below 100 organisms per 100 ml. In contrast to this, the two locations (A1 and A2) at the mouth of the Ausable (see section 5.1.1) had 57% of their samples with fecal coliform levels below 100 organisms per 100 ml. The data would therefore suggest that the river water quality improves in the lower reaches, possibly a result of bacterial sedimentation, die-off and dilution.

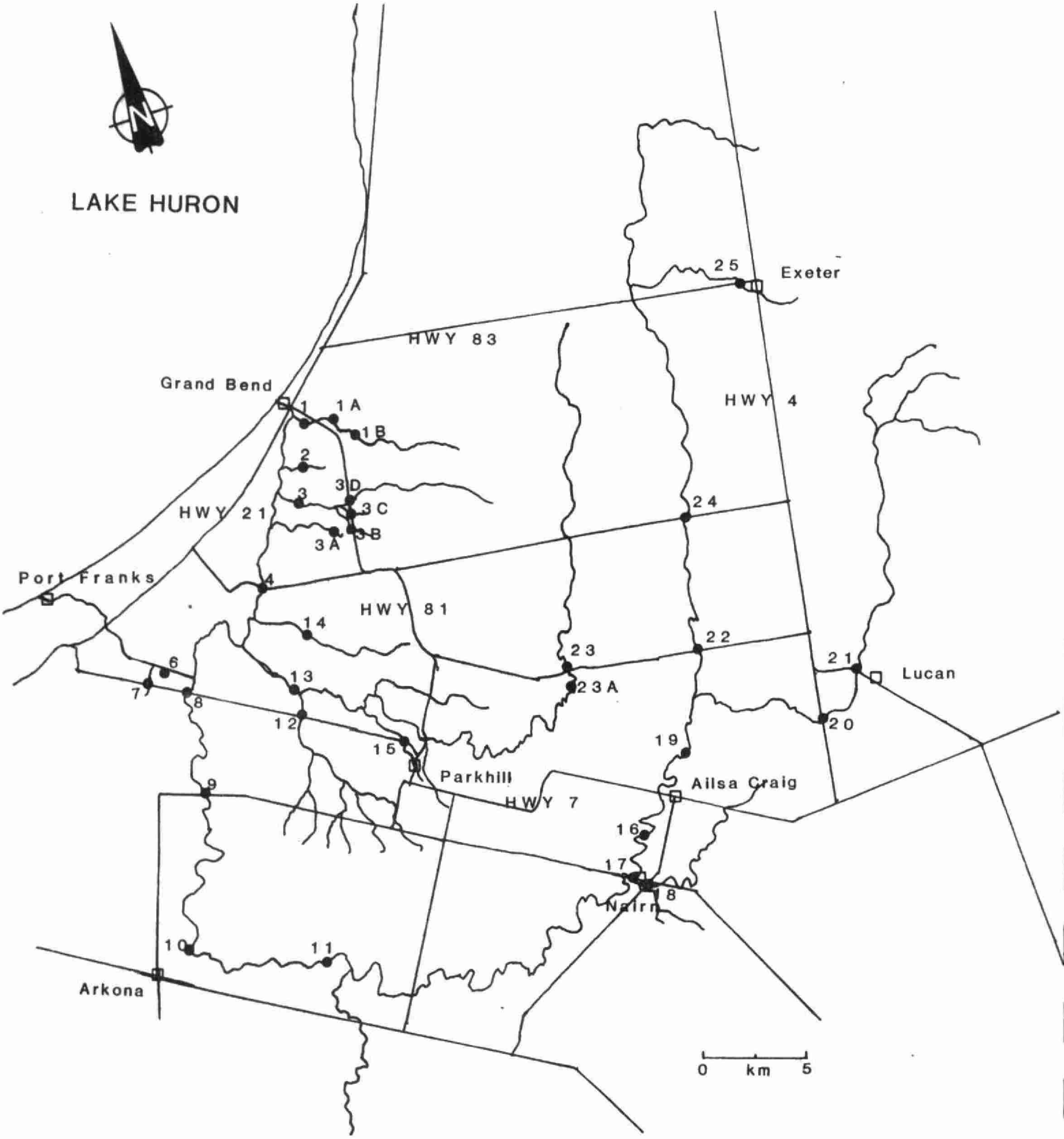


Figure 14. Sampling locations on the Ausable Watershed.

The watershed sampling revealed that all major branches of the Ausable have elevated levels of fecal bacteria. Because of the low ratio of urbanization to agriculturalization on the basin, and because of the fact that several of the sampling sites had only agriculture upstream, it can be concluded that the majority of the bacteriological impact on the Ausable is from agriculture. There are some locations on the basin where agriculture results in high bacterial contamination. At location 01, for example, levels of fecal coliform and fecal Streptococci ranged up to 152,000 and 21,000 per 100 ml, respectively.

5.4 Component 4 - Small Creeks

The 16 creeks sampled discharge to Lake Huron between Ipperwash Provicial Park and Goderich. These creeks or drains were sampled 5 to 9 times at the locations shown in Figure 15. Attempts were made to sample the sites in dry and wet weather conditions to best establish their potential to contribute bacterial loadings to the lake. The results of the sampling is shown in Table 2.

As can be observed, during various rainfall events, all the drainage water sampled contained elevated levels of fecal indicator bacteria. In addition, P aeruginosa, which was rarely recovered during dry weather sampling, was recovered at least on one occasion from most drains under wet weather sampling. Of the 16 drains sampled, drains 2, 4, 6, 7, 13 and 14 were considered to be particular problems. Individual samples from these creeks or drains contained fecal coliforms in excess of 20,000 bacteria per 100 ml and fecal Streptococci in excess of 10,000 bacteria per 100 ml.

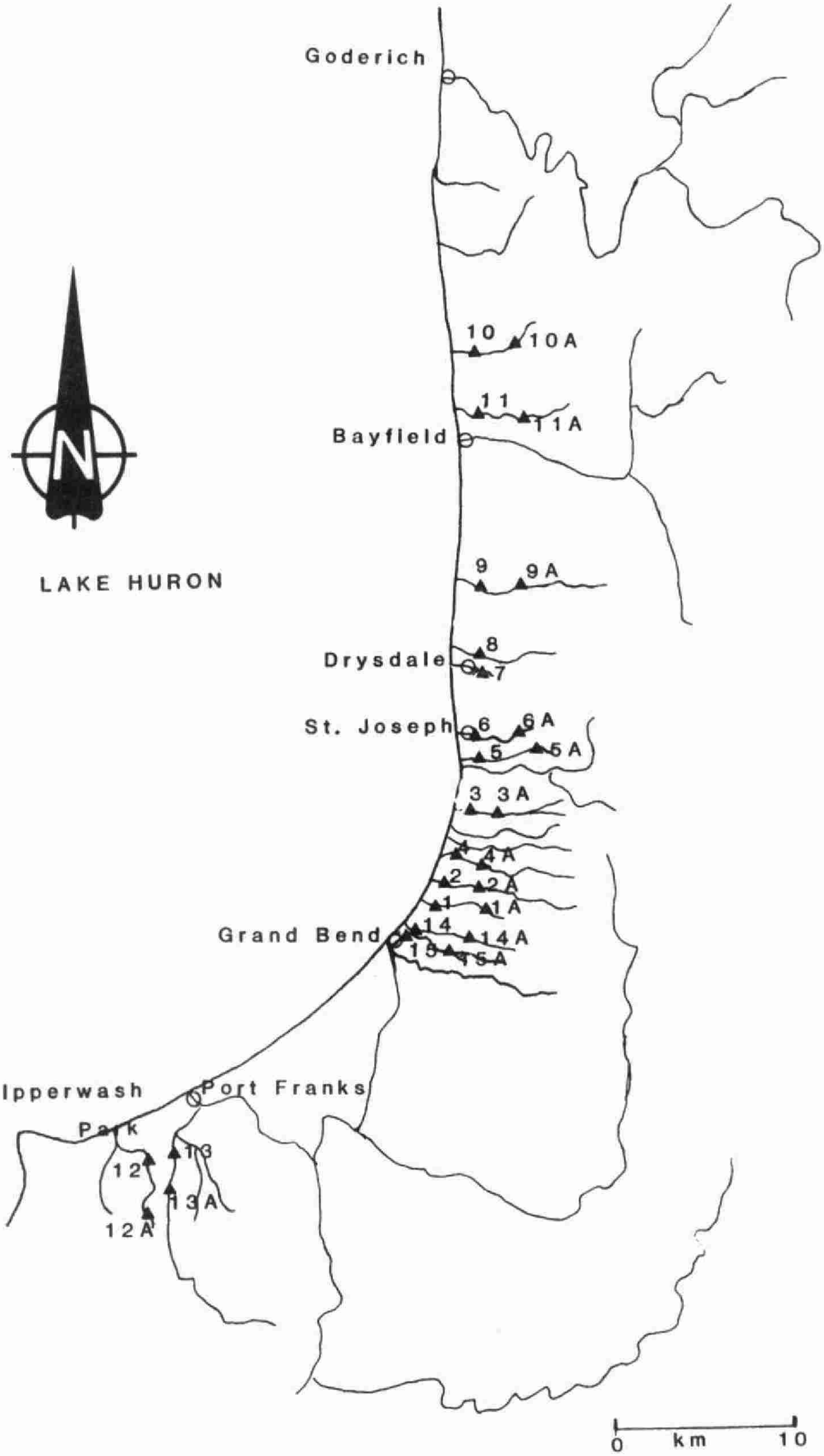


Figure 15. Sampling locations on the small creeks

Table 2. Geometric means of the wet and dry weather bacteriological data collected from the small creeks.

Station	Fecal Coliform #/100 ml		Fecal Streptococci #/100 ml		Pseudomonas aeruginosa #/100 ml	
	Wet	Dry	Wet	Dry	Wet	Dry
01	856	749	1970	683	L5	L4
01A	978		5310		33	
02	1775	305	2277	460	13	L4
02A	42000		46000		40	
03	969	2200	1138	1320	L4	L4
03A	10570		6609		L4	
04	11858	680	6602	50	129	10
04A	4893		10817		L7	
05	1265	670	1619	250	10	L4
05A	300		610		L4	
06	14603	3047	4653	1097	20	L4
06A	2907	1000	2711	700	22	L4
07	11036		3735		L4	
08	1819	431	429	200	L5	L4
09	4030	6300	1929	620	L8	L4
09A	6060	4700	5724	460	7	L4
10	191	570	310	184	L4	L4
11	1508	2826	2453	1528	L6	L4
11A	1205	1320	2504	240	L4	L4
12	1973	2000	2982	1460	L8	L4
12A	7389	31000	3066	6800	41	10
13	2810	259	1107	253	L27	L4
13A	1322	300	3667	3700	113	12
13B	900		1300		L4	
14	71723	24000	4808	603	28	10
14A	475		197		L4	
15	791	172	1155	168	L10	L4
15A	860		1678		L5	
16	662		889		L12	

One can try to differentiate between animal and human sources of the bacterial indicator organisms by using the fecal coliform to fecal Streptococcus ratio or the presence of elevated numbers of *P. aeruginosa*. Drain 6A, draining an agricultural land upstream of St. Joseph, was found to contain 5,000 and 15,300 fecal coliforms and fecal Streptococci respectively per 100 ml following a rain event on day 59; however, *P. aeruginosa* was not recovered. Consequently, this drain appears to have been contaminated by animal wastes, likely of agricultural origin. The drainage from drain 14 contained the highest levels of bacterial parameters measured under both wet and dry sampling. This drain is located immediately north of Grand Bend surrounded by cottages and summer homes. The data strongly suggests contamination by human wastes.

Although the impact of these contaminated creeks or drains on the lake was not directly assessed, it is apparent that it would affect the quality of the nearshore waters.

5.5 Component 5. Beach Quality With Regard to Time of Day and Distance from Shore

Study component 5 was divided into two parts:

a) sampling morning (9:00 a.m.), afternoon (2:00 p.m.) and evening (7:00 p.m.) at Grand Bend and Ipperwash

b) hourly sampling at Grand Bend

a) Two intensive studies were carried out at Grand Bend, and one at Ipperwash. Each intensive study involved the sampling of 5 "transects" at each beach at 9:00 a.m., 2:00 p.m. and 7:00 p.m. on each of three consecutive days.

On each transect, samples were collected at ankle depth (30 cm), waist depth (1.3 m) and neck depth (1.7 m). Hence, at each sampling time, a total of 15 samples were collected from each beach. Sample analyses included fecal coliforms, turbidity and conductivity. The two intensive studies at Grand Bend were carried out on days 17-19 and days 37-39. The one intensive study at Ipperwash was carried out on days 53-55.

The main purposes of these intensive studies were to determine the impact of swimmers and also to determine bacterial changes with water depth or distance from shore.

Table 3 outlines the numbers of swimmers in the water at the times of sampling. Figures 16, 17 and 18 illustrate the concentration of fecal coliforms that were found.

The following conclusions can be made from this part of the study:

1. At Grand Bend, fecal coliform bacteria levels tended to decrease somewhat with increased depth, but this pattern was certainly not consistent.

2. At Ipperwash, fecal coliform concentrations appeared to decrease greatly with increasing depth. This major difference, between Ipperwash and Grand Bend, in the fecal coliform/depth relationship, may relate in part to the differences in beach slope. With the much steeper beach slope at Grand Bend, the distances from the shallow locations (ankle depth) to the deep locations (neck depth) are relatively small. It is also of interest to note that under calm conditions, bacterial densities varied with time and location more so than under rough conditions.

Table 3. Record of the number of people swimming at each station during the two studies at Grand Bend beach and the study at the Ipperwash Provincial Park beach.

STATION NUMBER	DAY I 9 am	2 pm	7 pm	DAY II 9 am	2 pm	7 pm	DAY III 9 pm	2 pm	7 pm
Grand Bend Beach									
-010 05-GB-011 -012	0	0	0	0	10	0	0	16	0
-020 05-GB-021 -022	0	27	0	0	33	0	0	22	6
-030 05-GB-031 -032	0	0	0	0	20	0	0	23	0
-040 05-GB-041 -042	0	18	0	0	28	0	0	20	1
-050 05-GB-051 -052	0	0	0	0	14	2	0	29	0

Grand Bend Beach	9 am	2 pm	7 pm	9 am	2 pm	7 pm	9 pm	2 pm	7 pm
-010 05-GB-011 -012	0	0	0	0	2	0	0	0	0
-020 05-GB-021 -022	0	10	0	0	23	0	0	0	0
-030 05-GB-031 -032	0	5	0	0	11	0	0	0	0
-040 05-GB-041 -042	0	2	0	0	11	0	0	0	0
-050 05-GB-051 -052	0	11	0	0	9	0	0	0	0

Table 3. continued

STATION NUMBER	DAY I 9 am	2 pm	7 pm	DAY II 9 am	2 pm	7 pm	DAY III 9 pm	2 pm	7 pm
Ipperwash									
-010 05-I-011 -012	7	11	16	3	29	12	6	15	18
-020 05-I-021 -022	0	6	0	0	27	3	0	13	0
-030 05-I-031 -032	0	13	10	2	0	16	0	44	7
-040 05-I-041 -042	0	15	11	0	61	15	4	21	0
-050 05-I-051 -052	0	9	19	7	56	9	2	53	2

Figure 16. Three-day mean levels of fecal coliform in the beach water of Grand Bend at 9:00 a.m., 2:00 p.m. and 7:00 p.m. during the first intensive study.

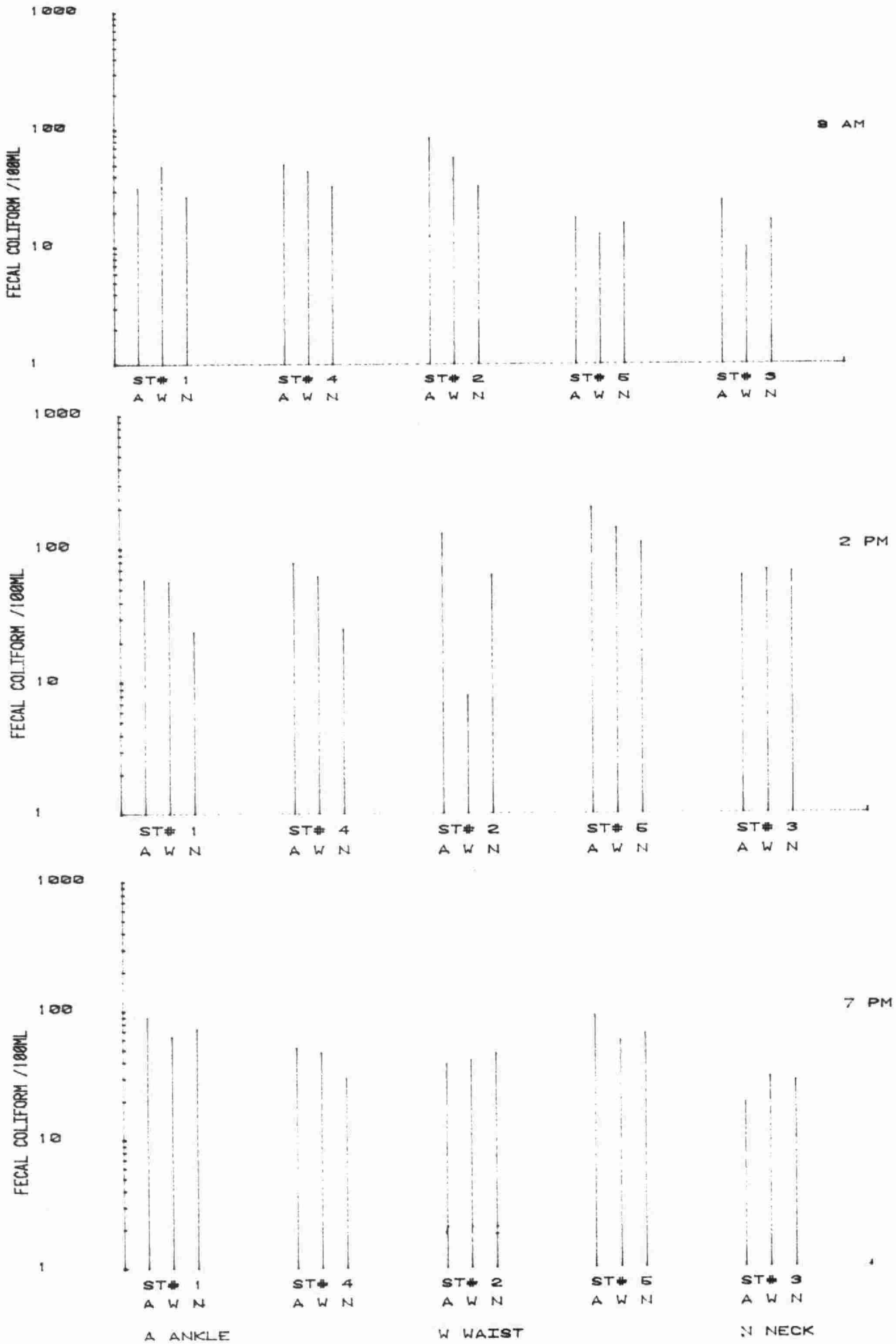


Figure 17. Three-day mean levels of fecal coliform in the beach water of Grand Bend at 9:00 a.m., 2:00 p.m. and 7:00 p.m. during the second intensive study.

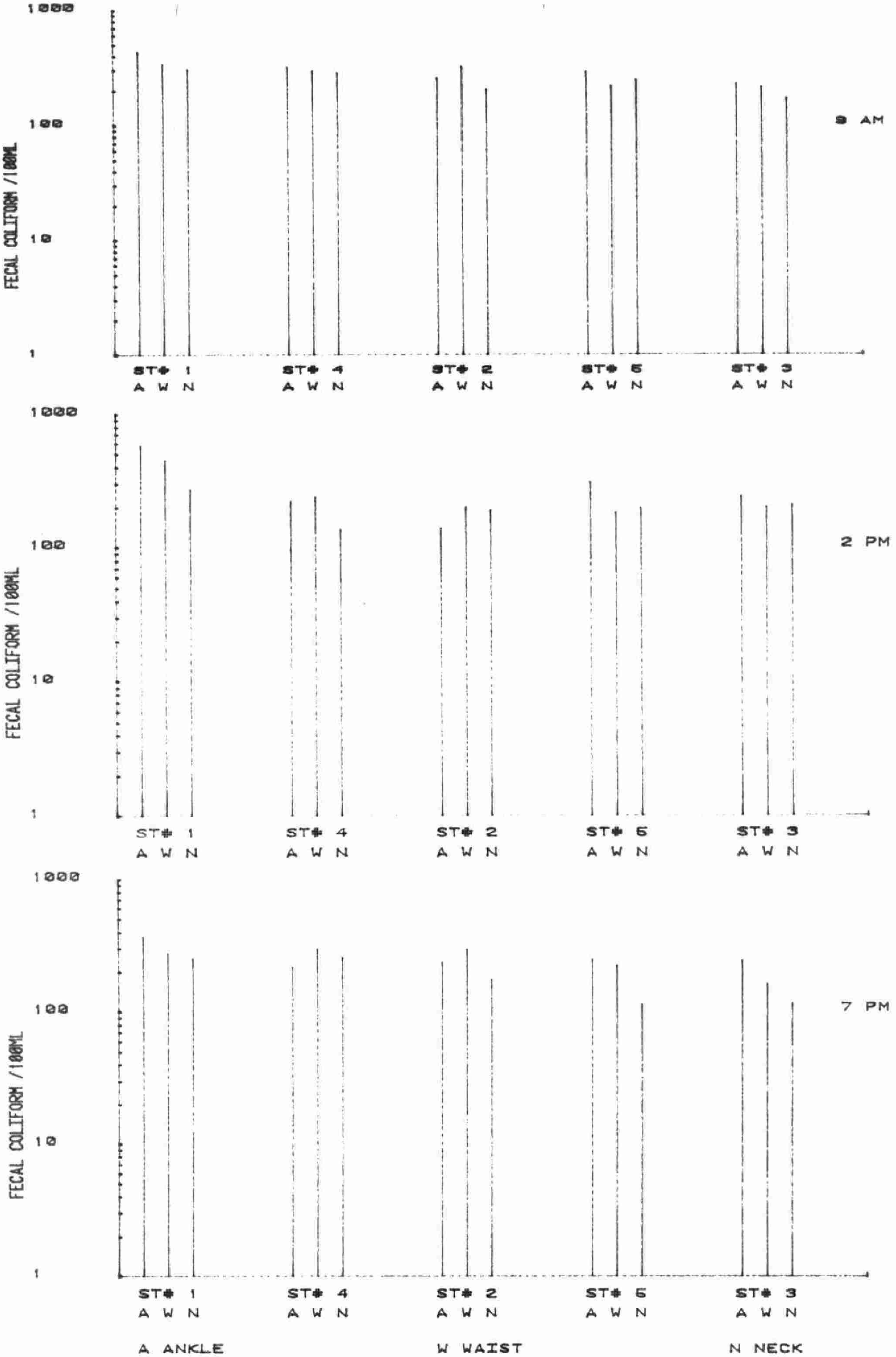
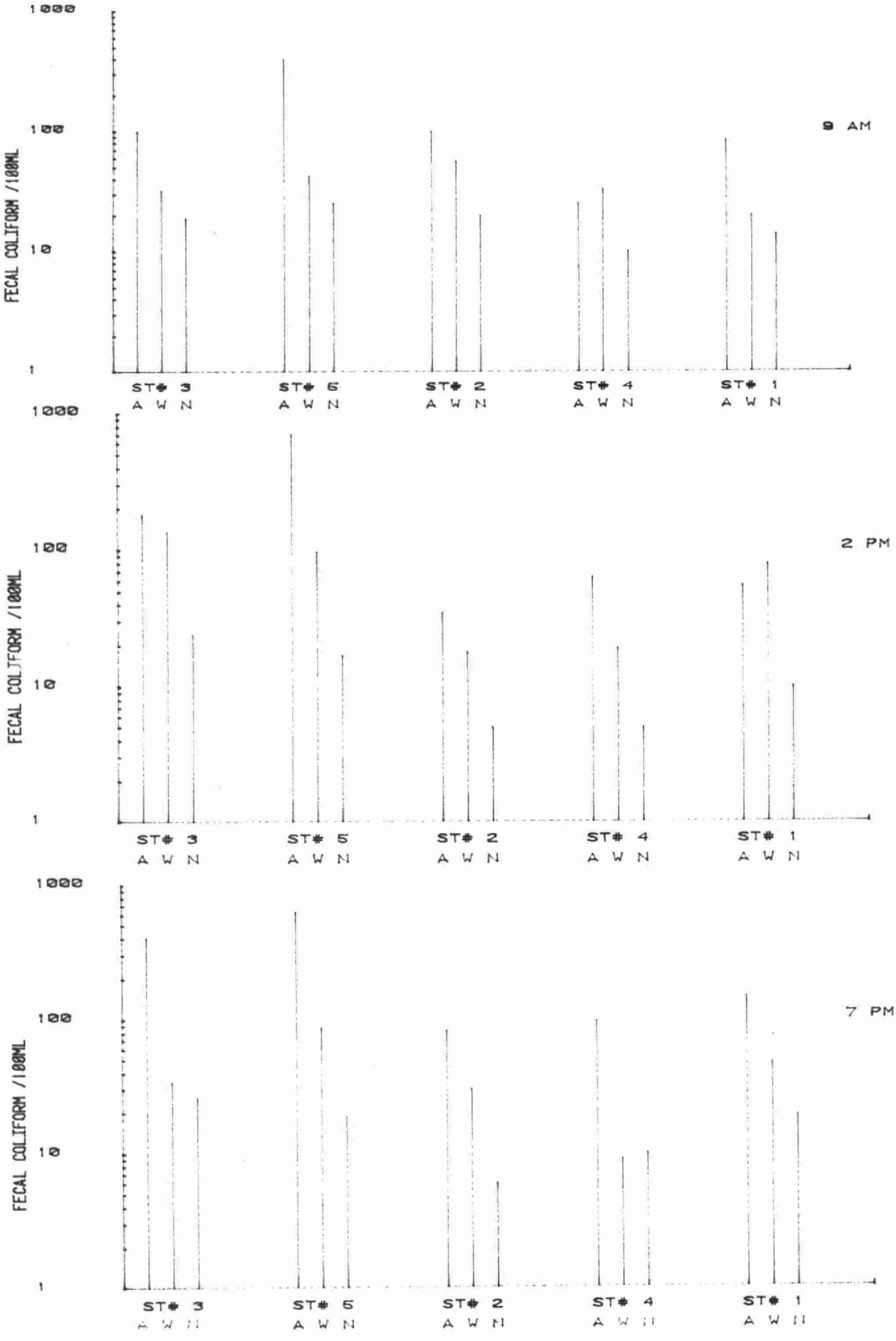


Figure 18. Three-day mean levels of fecal coliform in the beach water of Ipperwash Provincial Park at 9:00 a.m., 2:00 p.m. and 7:00 p.m.



3. There may be some correlation between bacterial levels and swimmer density. For example, Figure 17 illustrates an increase in fecal coliform bacteria, at 2:00 p.m., when swimmer density was relatively high. The correlation between bacterial levels and swimmer density may have been greater had calm-water conditions prevailed.

b) As part of study component 5, samples were collected hourly at the three routine sampling locations at Grand Bend. This work was carried out on July 22 and August 22. Figures 19-22 illustrate the fecal coliform and fecal Streptococci data. The data reveal that there are substantial differences hourly. There were, however, no apparent trends from morning to afternoon to evening.

5.6 Component 6. Dispersion of the Ausable and Maitland Rivers Into Lake Huron

Five separate dispersion studies were conducted over the course of the entire study to assess the potential for the two rivers to affect the bathing beaches. The concept used in the studies involved the use of conductivity gradients to identify the river water plume as it mixed with lake water. Measurements from a model 33 YSI conductivity meter were taken at various transects across the river and in the lake to determine the size and direction of the dispersion flow of the river water. Wind speed and direction were also obtained during the sampling runs.

Maitland River

During the initial run on August 8, the wind was from the southeast ranging from 0 - 15 km/hr. The river plume moved directly north and parallel with the shoreline

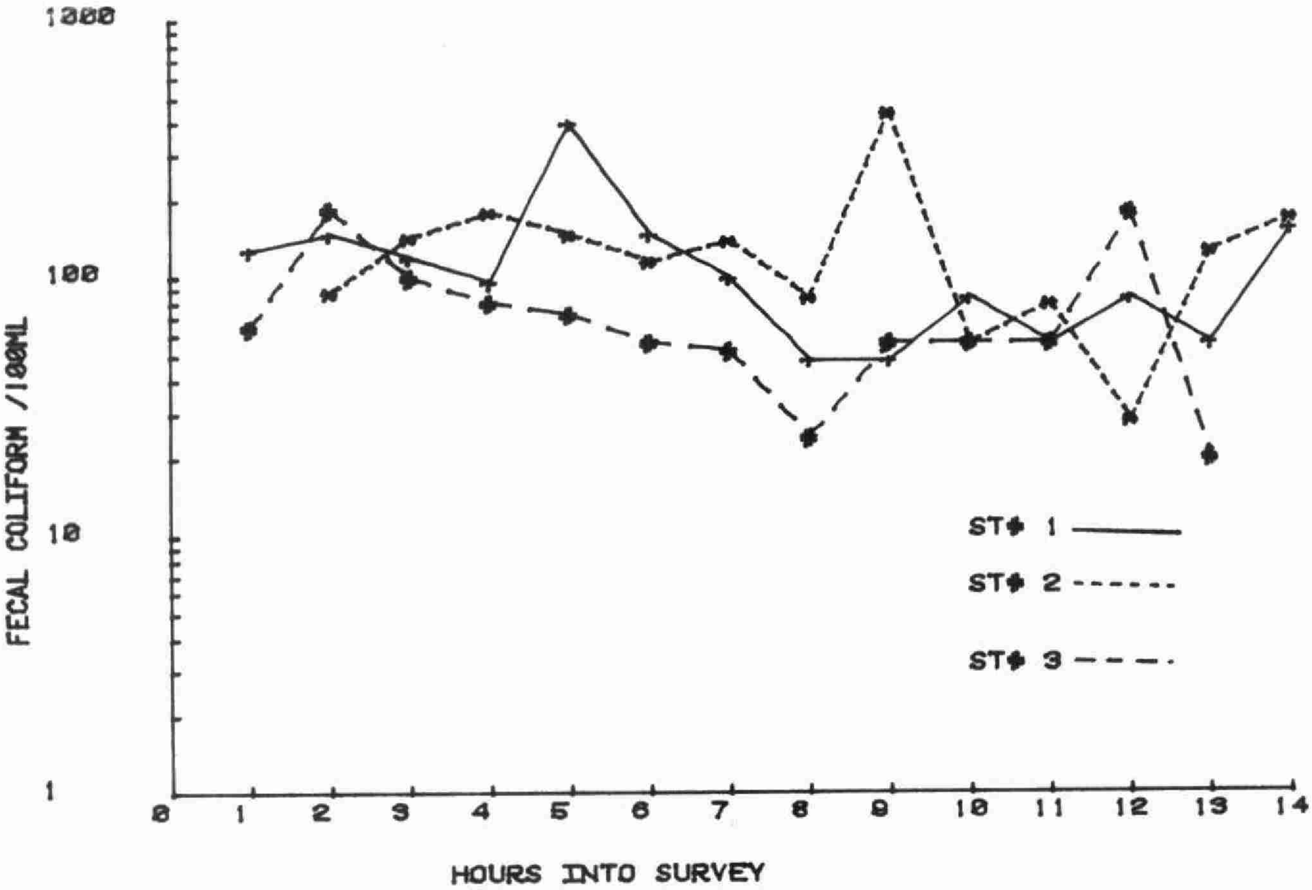


Figure 19. Levels of fecal coliform in the beach water of Grand Bend during the first hourly intensive.

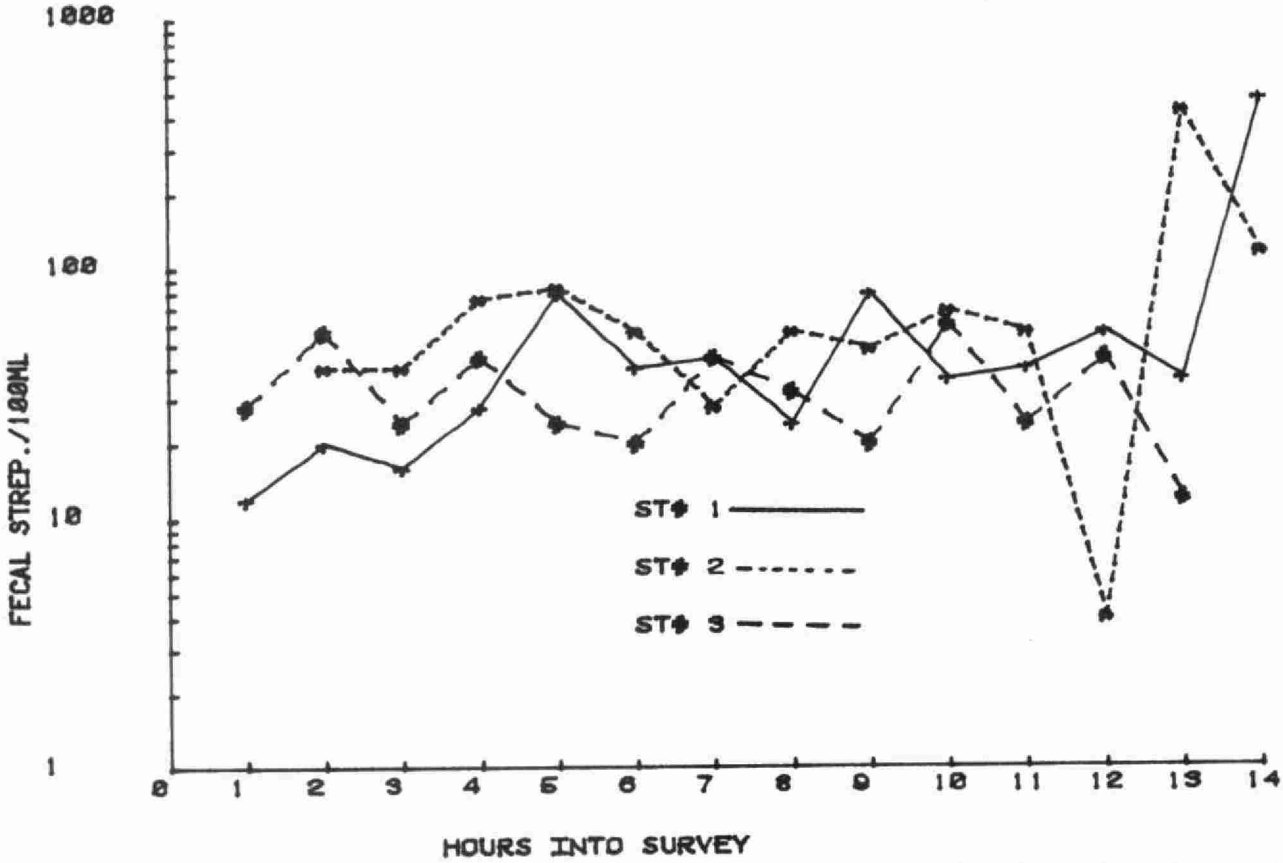


Figure 20. Levels of fecal streptococci in the beach water of Grand Bend during the first hourly intensive.

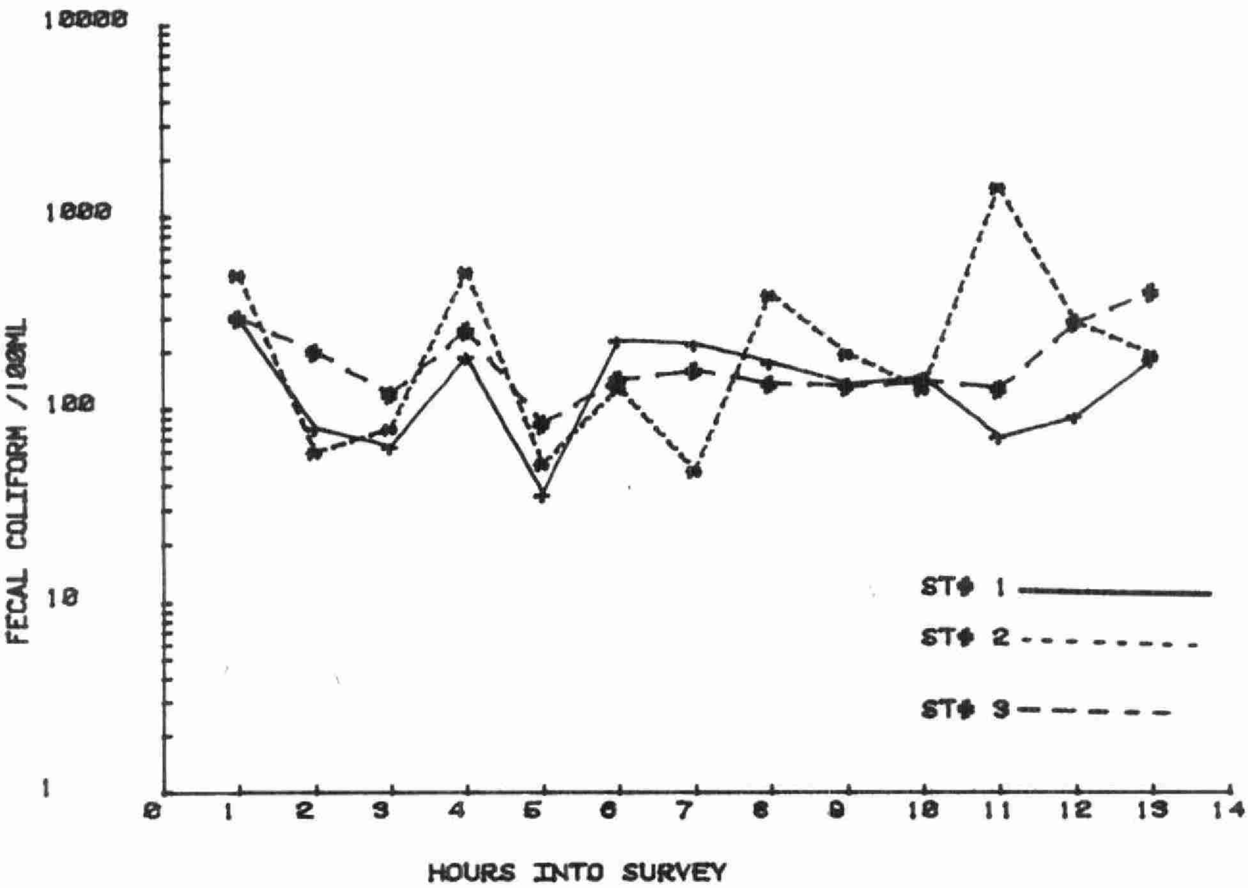


Figure 21. Levels of fecal coliforms in the beach water of Grand Bend during the second hourly intensive.

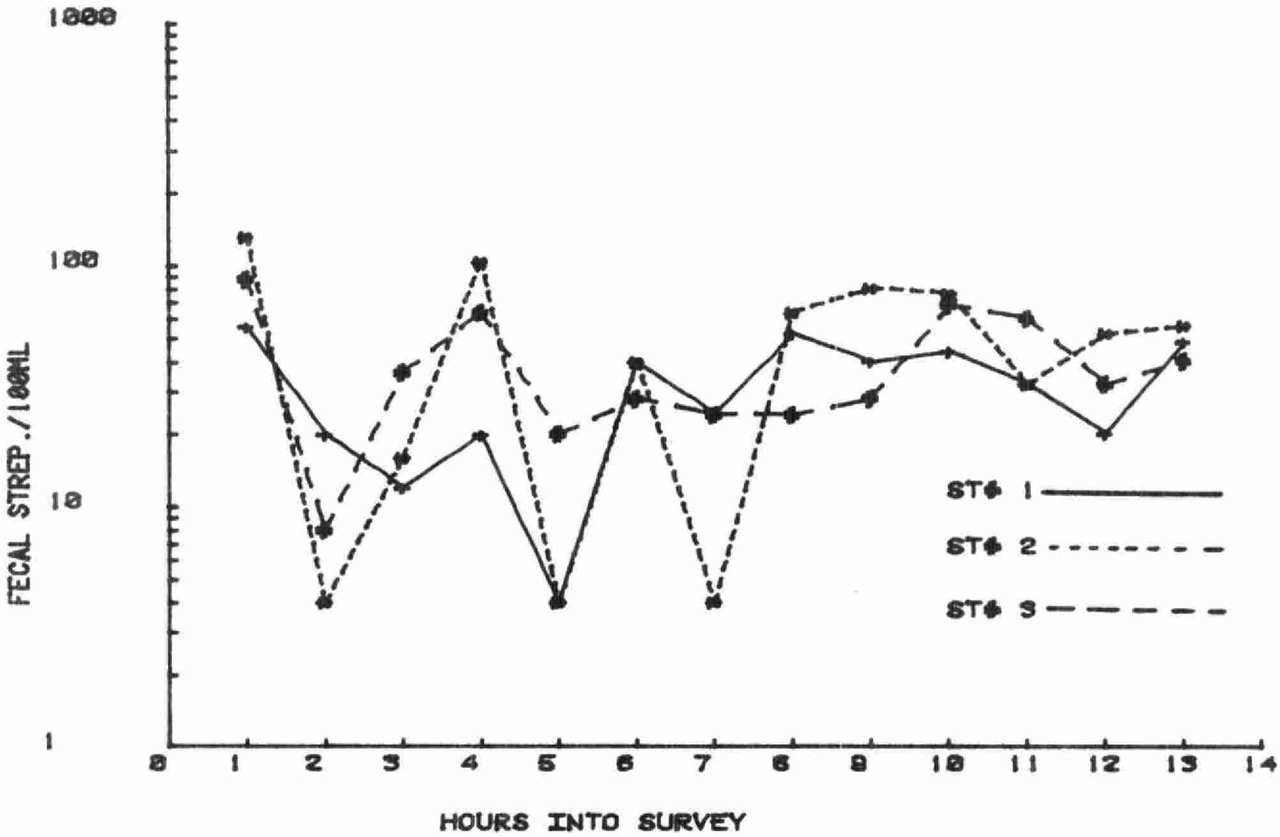


Figure 22. Levels of fecal streptococci in the beach water of Grand Bend during the second hourly intensive.

for approximately 0.5 km before it was lost to the background. During the run on August 16, the wind was from the northwest at 15 km/hr which resulted in the plume moving westerly and dissipating within the breakwalls. On August 29 the wind was again from the southwest at 18.5 to 46.5 km/hr. The resultant river plume was similar to the first study moving north parallel to the shoreline.

From the three runs conducted, the river water could easily be detected using conductivity as a tracer. The river typically had a conductivity of approximately 2,000 umhos/cm^3 while the lake was in the 200 to 210 umhos/cm^3 range.

Ausable River

Assessments of the dispersion pattern of the Ausable River were made on August 16 and 29 using the same procedure as mentioned above. On the first run, the wind was from the northwest at 15 km/hr while in the second run the wind was from the northeast at approximately 9 km/hr. In both cases, the conductivity plume dissipated by the end of the breakwalls. The river conductivity was in the 500 umhos/cm^3 range.

5.7 Component 7. Sanitary Surveys at Grand Bend

The study included periodic sampling of the Grand Bend storm sewers. During the initial storm sewer sampling, 24 storm drainage outlets were sampled. Subsequent sampling was reduced, with more concentrated effort on those drainages carrying elevated bacterial levels.

Most of the storm drainage sampled showed low to moderate fecal bacterial levels which is "normal" for storm sewer systems. Three sewers, however, did have elevated bacterial levels. The most contaminated drain, W-5, which discharges to the Walker Drain, has been reported for follow-up action.

5.8 Component 8. Sanitary Surveys at Goderich

This sanitary survey involved the sampling of storm sewers in Goderich, as well as the discharge from the Goderich sewage treatment plant.

Some of the storm sewer samples did contain elevated levels of fecal bacteria during and following rainfall events. Follow-up is required.

The effluent from the Goderich sewage treatment plant was found to be adequately disinfected. A major storm sewer combines with the Goderich STP effluent before being discharged to the lake. Analyses indicated that the disinfected effluent of the STP contained sufficient chlorine residual to also disinfect this major storm sewer.

5.9 Component 9. Inventory of Sewage By-Pass

As part of the beach study, it was necessary to be aware of any bypassing of raw sewage or primary treated sewage to Lake Huron or any of the watercourses which drain into the lake between Ipperwash and Goderich. Personnel of all pollution control plants and lagoon systems in this area were requested to contact the Ministry of the Environment in case of any sewage bypassing or plant upsets.

The records indicated little to no problem. Only one facility, the Huron Park Pollution Control Plant, indicated a bypass event.

5.10 Component 10. Contamination of Walker Drain and Duffus Creek

During the course of the study, two localized areas of badly contaminated surface waters were located - the Walker Drain at Grand Bend and Duffus Creek at Ipperwash. Component #10 of the study simply involved a

detailed survey of these two areas of concern, and corrective efforts.

Walker Drain

From the assessment of the quality of storm sewers within Grand Bend, it became apparent that the stormwater from a trailer park within the village limits was being contaminated with fecal material. An additional seven sites were sampled within the trailer park, along with upstream samples. From the upstream sampling, it was determined that a nearby farm septic tank was hydraulically connected to a farm drainage tile discharging to the drain. This problem, along with the ones identified within the trailer park, were passed on to the health unit for follow-up.

Duffus Creek

During routine sampling (Component 1) of the Duffus Creek which discharges into Lake Huron at the Ipperwash Provincial Park beach, it became apparent that the levels of fecal coliform bacteria were increasing substantially after day 25 of the study. Five additional sampling locations (see Figure 23) were established on the various branches and sampled for five consecutive days. The results indicated that all sites were contaminated to varying degrees with fecal wastes. The branch that drained through a trailer park and the cadet army camp was particularly elevated with fecal indicator bacteria. A further 9 stations (see Figure 24) were established on this one branch of the drain. Samples of the storm water drainage from the cadet camp contained higher fecal indicator bacteria levels than the samples taken from the sanitary sewer (see Table 4). It was obvious from these results, that the stormwater was heavily contaminated with

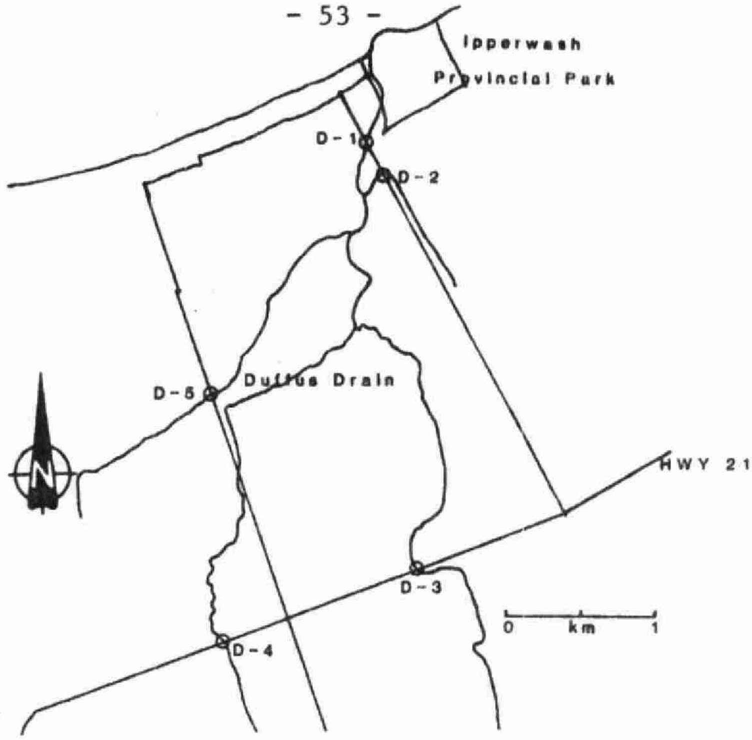


Figure 23. Location of stations sampled on the Duffus Drain during the Lake Huron Beach study.

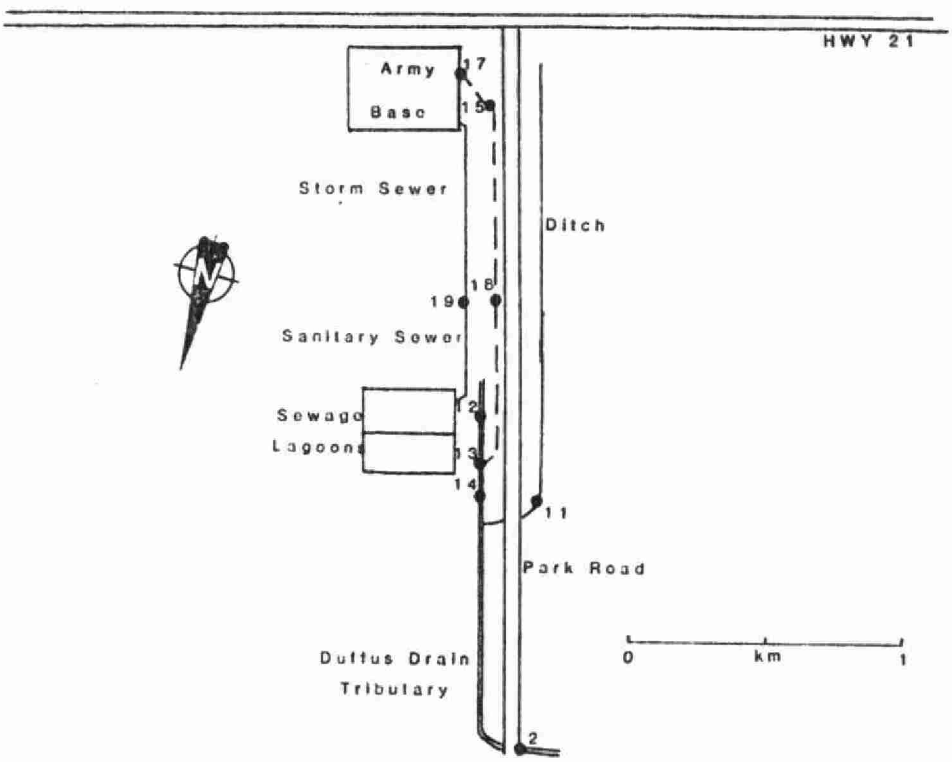


Figure 24. Location of sampling sites of storm sewers within the Army Cadet Camp property.

Table 4. Results of a bacteriological investigation of the storm drainage of the Ipperwash Army Base and the Duffus Drain

Station Number	Map Number	Fecal Coliforms	Fecal <u>Streptococci</u>	<u>Pseudomonas aeruginosa</u>
		(Bacterial levels expressed per 100 mL)		
1	2	98,000	220	24
2	11	10,400	390	100
3	12	A200	700	L4
4	13	G1,500,000	G150,000	8,500
5	14	G1,500,000	G15,000	13,000
6	15	G1,500,000	150,000	8,500
7	17	2,500,000	420,000	G15,000
8	18	G15,000,000	G150,000	G15,000
9	19	6,900,000	340,000	7,900

G = greater than

raw sewage which was emanating from a source or sources in the buildings on the army base. The storm sewer was temporarily plugged and the water pumped over to the sanitary line and thus to the sewage lagoon. The impact of this corrective measure can be seen in Figure 7, where the bacterial levels in Duffus Creek decrease. Additional assessment of this situation will hopefully be carried out during 1985.

5.11 Component 11. Boat Inspections

Inspection of boats at the Grand Bend and Bayfield marinas were conducted to determine if proper waste holding facilities were in place and functionable according to Ontario Regulation 305.

A total of 48 boats were inspected at the Bayfield marinas on the holiday weekends of July 1 and August 1. Following the investigations, three boats were found in violation and the operators were fined.

The inspection of the boats at Grand Bend were conducted on three holiday weekends plus four additional weekends in June and July. None of the 112 boats inspected were found to be in violation.

Of the 160 boats investigated at the two harbours, only 1.8% did not comply with Regulation 305. It was concluded from the above that pleasure craft were not contributing significantly to the fecal pollution of the beach water due to faulty waste holding equipment.

5.12 Component 12. Impact of Marina Areas

Some work done in 1983 at Goderich, Bayfield and Grand Bend indicated that marina areas may be a source of bacteria. Hence, in 1984, this study activity was initiated to better define the potential of high densities of boats to pollute harbour water. Although from previous boat inspections, it was determined that boats in general had proper sewage-holding facilities, grey-water discharges could theoretically still present a problem.

Figure 25 illustrates the stations that were sampled upstream and downstream of marina areas. Tables 5, 6 and 7 indicate the sampling frequency, and the results.

In general, the data were inconclusive. It would appear that if there was a bacteriological impact of marinas on the beaches, it was probably minor.

5.13 Specialized Microbiology Work

5.13.1 Antibiotic-Resistance

Isolates of the fecal coliform bacteria *Escherichia coli* and the pathogenic bacterium, *Pseudomonas aeruginosa* were tested for their possible resistance to 10 antibiotics which are commonly used to eliminate these organisms.

From the results shown in Table 8, it can be observed that *E. coli* were consistently resistant to the three antibiotics, cephalothin, sulfisoxazole and tetracycline. However, some isolates were also resistant to carbenicillin, gentamycin, kanamycin and piperacillin. The resistance of some isolates to 8 antibiotics is of concern, for although the ability of most isolates to cause disease

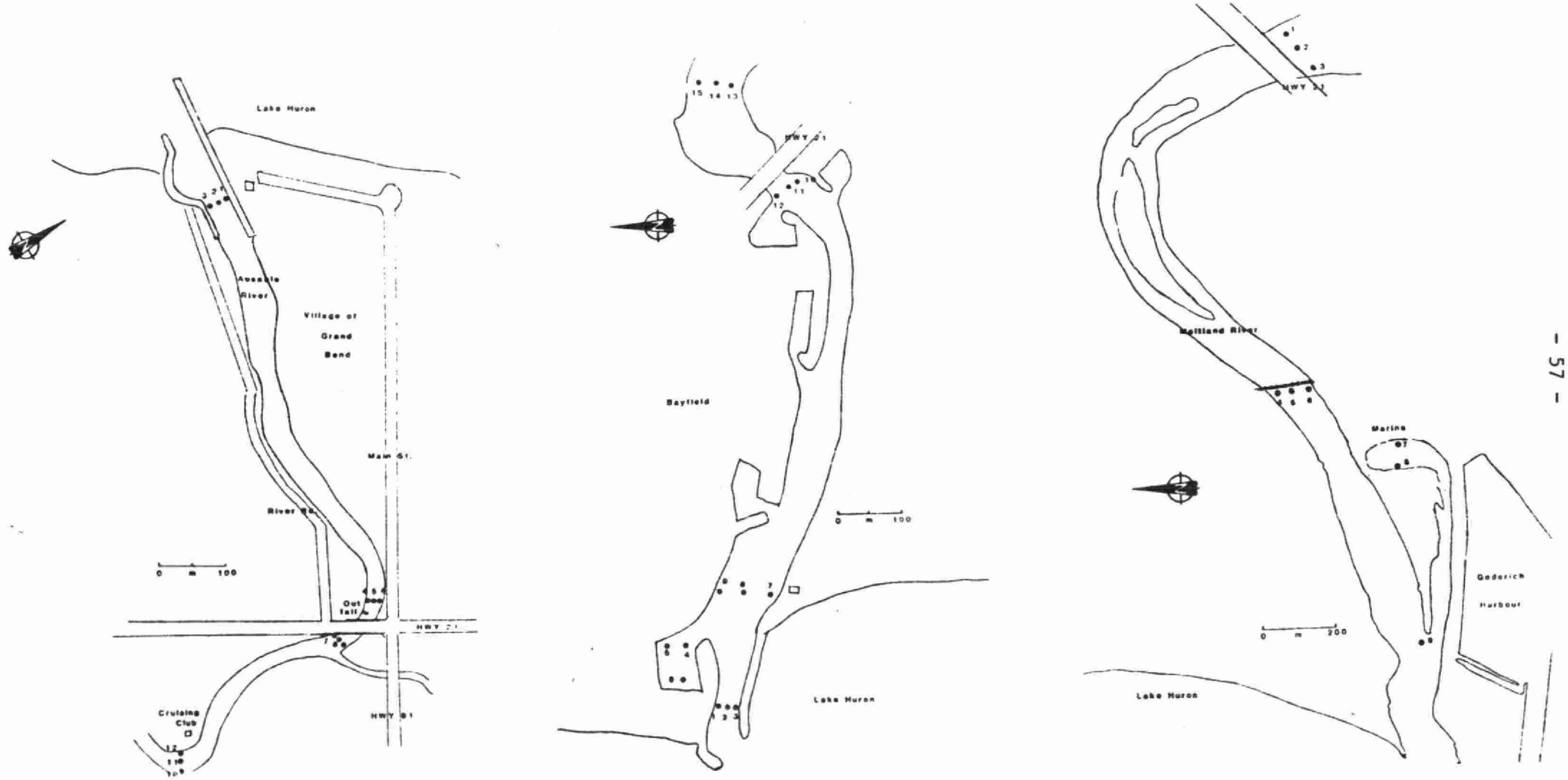


Figure 25. Location of stations at Grand Bend, Bayfield and Goderich used during the study to determine impact of marina areas on water quality.

Table 5. Concentrations of fecal indicator bacteria as determined at the marina at Grand Bend and the Ausable River

	Station Number		Marina Fecal Coliforms		Fecal Streptococci	Grand Bend	P. aeruginosa	
			(Numbers of bacteria - geometric mean per 100 mL)					
	1		143.2		114.2		6.3	
Transect	2		174.7		206.7		14.7	
1	3		188.7		56.9		8.0	
		*Transect Mean		168.9		125.9		9.7
	4		99.0		118.5		5.0	
Transect	5		84.5		71.0		6.8	
2	6		115.4		153.9		7.3	
		*Transect Mean		99.6		114.5		6.4
	7		75.5		90.1		8.0	
Transect	8		99.4		78.6		6.8	
3	9		92.2		110.6		8.6	
		*Transect Mean		89.0		93.1		7.8
	10		61.7		70.2		6.3	
Transect	11		35.0		71.1		4.0	
4	12		59.7		69.9		7.3	
		*Transect Mean		52.1		70.4		5.9

*Transect Mean = arithmetic average

Table 6. Concentrations of fecal indicator bacteria as determined at the marina at Bayfield and the Bayfield River

			Marina		Bayfield			
	Station Number		Fecal Coliforms		Fecal Streptococci		*P. aeruginosa*	
			(Numbers of bacteria - geometric mean per 100 mL)					
	1		25.3		49.1		7.3	
Transect	2		32.7		27.0		5.0	
1	3		32.5		49.0		5.7	
		*Transect Mean		30.2		41.7		6.0
	4		16.6		15.9		4.0	
Transect	5		25.3		68.8		8.9	
2	6		41.9		13.7		4.0	
		*Transect Mean		27.9		32.8		5.6
	7		59.8		27.3		4.0	
Transect	8		43.8		20.0		8.0	
3	9		46.2		34.0		4.0	
		*Transect Mean		49.9		27.1		5.3
	10		206.2		71.9		9.4	
Transect	11		194.4		69.1		7.7	
4	12		202.0		65.3		8.3	
		*Transect Mean		200.9		68.8		8.5
	13		101.9		54.9		4.0	
Transect	14		65.4		28.6		4.0	
5	15		46.6		32.6		4.0	
		*Transect Mean		71.3		38.7		4.0

*Transect Mean = arithmetic average

Table 7. Concentrations of fecal indicator bacteria as determined at the marina at Goderich and the Maitland River

	Station Number	Marina		Goderich
		Fecal Coliforms	Fecal Streptococci	P. aeruginosa
		(Numbers of bacteria - geometric mean per 100 mL)		
	1	50	152	8
Transect	2	56	600	48
1	3	48	600	100
	*Transect Mean	51.3	450.7	52
	4	84	180	L4
Transect	5	104	296	L4
	6	48	172	L4
	*Transect Mean	78.7	216	8
	7	48	172	L4
Transect	8	340	12	L4
	*Transect Mean	194	92	L4
	9	124	16	4
Transect	10	100	120	L4
	*Transect Mean	112	68	2

*Transect Mean = arithmetic average

Table 8. Frequency and distribution of resistance to antibiotics among <u>E. coli</u> isolated from recretional waters of Lake Huron and potential pollution sources.

Location	Amp	Car	Cep	Col	Co-t	Gen	Kan	Pip	Sul	Tet
	Antibiotics									
	Numbers = % Resistant/(numbers tests)									
Grand Bend Beach	11.1 (1)	11.1 (1)	100 (9)	0 (9)	0 (9)	11.1 (1)	33.3 (3)	11.1 (1)	66.6 (6)	100 (9)
Ausable River	16.7 (1)	0 (6)	83.3 (5)	0 (6)	0 (6)	33.3 (2)	16.7 (1)	0 (6)	100 (6)	83.3 (5)
Creeks into Ausable River	0 (8)	0 (8)	100 (8)	0 (8)	0 (8)	37.5 (3)	0 (8)	0 (8)	100 (8)	100 (8)
Ipperwash Park Beach	11.1 (1)	0 (9)	100 (9)	0 (9)	0 (9)	11.1 (1)	0 (9)	0 (9)	33.3 (3)	77.8 (7)
Duffus Drain	0 (4)	0 (4)	100 (4)	0 (4)	0 (4)	0 (4)	0 (4)	0 (4)	100 (4)	100 (4)
Agr. Drains 12,13 (near Ipperwash)	0 (3)	0 (3)	66.7 (2)	0 (3)	0 (3)	0 (3)	0 (3)	0 (3)	100 (3)	100 (3)
Goderich Harbour Beach	0 (9)	0 (9)	66.7 (6)	0 (9)	0 (9)	0 (9)	0 (9)	0 (9)	100 (9)	100 (9)
Maitland River	0 (6)	0 (6)	83.3 (5)	0 (6)	0 (6)	16.7 (1)	0 (6)	0 (6)	100 (6)	100 (6)
Goderich Storm-sewers	14.3 (3)	19 (4)	95.2 (20)	0 (21)	0 (21)	9.5 (2)	0 (21)	14.3 (3)	33.3 (7)	85.7 918)

Amp - Ampicillin, Car - Carbenicillin, Cep - Cephalothin, Col - Colistin, Co-t - Co-trimoxazole, Gen - Gentamycin, Kan - Kanamycin, Pip - Piperacillin, Sul - Sulfisoxazole, Tet - Tetracycline

Table 8. Continued

	Antibiotics									
	Amp	Car	Cep	Col	Co-t	Gen	Kan	Pip	Sul	Tet
	Numbers = % Resistant/(numbers tests)									
Location										
Agr. Drains 11,11A (near Goderich)	0 (4)	0 (4)	100 (4)	0 (4)	0 (4)	50 (2)	0 (4)	0 (4)	100 (4)	100 (4)
Bayfield River	0 (3)	0 (3)	100 (3)	0 (3)	0 (3)	0 (3)	0 (3)	0 (3)	100 (3)	100 (3)

Amp - Ampicillin, Car - Carbenicillin, Cep - Cephalothin, Col - Colistin, Co-t - Co-trimoxazole, Gen - Gentamycin, Kan - Kanamycin, Pip - Piperacillin, Sul - Sulfisoxazole, Tet - Tetracycline

is unlikely, the ingestion of these organisms while swimming could subsequently result in the transfer of the resistance to other pathogenic bacteria in the intestine. The disease-causing bacteria such as Salmonella, Shigella and Pseudomonas once acquiring these resistance factors are then better able to evade treatment with antibiotics, while producing infection.

The antibiotic-resistance patterns determined on P. aeruginosa isolates demonstrated resistance to typically seven antibiotics as shown in Table 9. It is probable that infections caused by these bacteria that have multiple-resistance to antibiotics which may be acquired while swimming would be more difficult to treat.

Antibiotic resistance occurs as a result of a bacterium coming in frequent contact with the antibiotic. The resistance patterns demonstrated by both the E. coli and P. aeruginosa isolates are in general typical of those antibiotics used most commonly by veterinarians and farmers (see Table 10). Hence, these data suggest that the majority of the bacteria recovered from the beach water are likely of agricultural origin.

5.13.2 Bacterial Serotyping

To better determine the origin of the P. aeruginosa isolates, they were further identified by a serotyping procedure.

The results shown in Table 11 indicate the serotype of isolates from the three beaches studied, as well as possible pollution sources. In the case of Grand Bend, it can be observed that the specific serotype 017 recovered in the beach water was also found at station 03-A-2 which is a small tributary of the Ausable River near Grand Bend.

Table 9. Frequency and distribution of resistance to antibiotics among <u>Pseudomonas aeruginosa</u> isolated from recreational waters of Lake Huron and potential pollution sources.

Location	Amp	Car	Cep	Col	Co-t	Gen	Kan	Pip	Sul	Tet
	Numbers = % Resistant/(number tests)									
Grand Bend Beach	100 (6)	0 (6)	100 (6)	0 (6)	100 (6)	100 (6)	100 (6)	0 (6)	83.3 (5)	100 (6)
Ausable River 0-19-2	100 (5)	0 (5)	100 (5)	0 (5)	100 (5)	100 (5)	100 (5)	0 (5)	100 (5)	100 (5)
Creeks (in Ausable) 2,3A	100 (4)	0 (4)	100 (4)	0 (4)	100 (4)	75 (3)	100 (4)	0 (4)	100 (4)	100 (4)
Grand Bend Stormsewers	100 (3)	0 (3)	100 (3)	0 (3)	100 (3)	100 (3)	100 (3)	0 (3)	100 (3)	100 (3)
Agr. Drains 4,5 (near Grand Bend)	100 (4)	0 (4)	100 (4)	0 (4)	100 (4)	50 (2)	100 (4)	0 (4)	100 (4)	100 (4)
Port Blake	100 (3)	0 (3)	66.7 (2)	0 (3)	66.7 (2)	100 (3)	66.7 (2)	0 (3)	100 (3)	66.7 (2)
Goderich Harbour Harbour Beach	100 (3)	0 (3)	100 (3)	0 (3)	100 (3)	100 (3)	100 (3)	0 (3)	100 (3)	100 (3)
Maitland River	100 (2)	0 (2)	100 (2)	0 (2)	100 (2)	100 (2)	100 (2)	0 (2)	100 (2)	100 (2)
Goderich Storm-sewers	100 (8)	0 (8)	100 (8)	0 (8)	100 (8)	100 (8)	100 (8)	0 (8)	87.5 (7)	100 (8)
Goderich STP	100 (2)	0 (2)	100 (2)	0 (2)	100 (2)	100 (2)	100 (2)	0 (2)	100 (2)	100 (2)
Goderich STP Combined Outfall	100 (2)	50 (1)	100 (2)	0 (2)	100 (2)	100 (2)	100 (2)	0 (2)	100 (2)	100 (2)

Amp - Ampicillin, Car - Carbenicillin, Cep - Cephalothin, Col - Colistin, Co-t - Co-trimoxazole, Gen - Gentamycin, Kan - Kanamycin, Pip - Piperacillin, Sul - Sulfisoxazole, Tet - Tetracycline

Table 9. Continued

Location	Amp	Car	Cep	Col	Co-t	Gen	Kan	Pip	Sul	Tet
	Antibiotics									
	Numbers = % Resistant/(numbers tests)									
Agr. Drain 9,9A (near Bayfield)	100 (4)	0 (4)	100 (4)	0 (4)	100 (4)	100 (4)	100 (4)	0 (4)	100 (4)	100 (4)
Ipperwash Park Beach	100 (8)	12.5 (1)	100 (8)	0 (8)	100 (8)	87.5 (7)	100 (8)	0 (8)	87.5 (7)	100 (8)
Duffus Creek	100 (6)	0 (6)	100 (6)	0 (6)	100 (6)	100 (6)	100 (6)	0 (8)	100 (6)	100 (6)
Agr. Drains 12,12A 13A,13AA (near Ipperwash)	100 (8)	0 (8)	100 (8)	0 (8)	100 (8)	87.5 (7)	100 (8)	0 (8)	100 (8)	100 (8)

Amp - Ampicillin, Car - Carbenicillin, Cep - Cephalothin, Col - Colistin, Co-t - Co-trimoxazole, Gen - Gentamycin, Kan - Kanamycin, Pip - Piperacillin, Sul - Sulfisoxazole, Tet - Tetracycline

Table 10. Usage of specific antibiotics against *Escherichia coli*, and *Pseudomonas aeruginosa* and other gram-negative bacteria by veterinarians and physicians.

Antibiotic	Veterinarians		Physicians	
	Degree of Usage			
	Common	Rare	Common	Rare
Ampicillin	+		+	
Carbenicillin		+	+	
Cephalothin		+	N	
Colistin		+	N	
Co-trimoxazole	+		+	
Gentamycin	+			+
Kanamycin	+			+
Piperacillin	N			+
Sulfisoxazole	+		N	
Tetracycline	+		N	

N = not used

Table 11. Distribution of serotypes of Pseudomonas aeruginosa as detected in recreational waters along the shores of Lake Huron and various pollution sources.

	Location					
	Grand Bend Beach	Ausable River	Agr. Drains (near Grand Bend)	Ipperwash Park Beach	Duffus Creek	Agr. Drains (near Ipperwash)
Serotypes - (number isolated)	01 - (2) 03 - (4) 06 - (1) 017 - (2)	01 - (1) 02 - (2) 06 - (5) 07 - (1) 07,8 - (1) 015 - (1) 017 - (1)	01 - (1) 03 - (1)	01 - (2) 02 - (2) 07 - (2) 016 - (1) 017 - (1)	01 - (3) 015 - (3)	01 - (2) 06 - (3) 09 - (1) 013 - (1) 015 - (1)

	Location			
	Goderich Harbour Beach	Goderich Stormsewers	Goderich STP	Maitland River
Serotypes - (number isolated)	011 - (3)	01 - (1) 03 - (3) 04 - (1) 06 - 8 015 - (1)	06 - (2)	06 - (1)

	Location	
	Agr. Drain (near Bayfield)	Port Blake
Serotypes - (number isolated)	014 - (1) 015 - (3)	01 - (1) 02 - (1) 03 - (1)

Additional serotypes found in the beach water could also be related to a source in this manner. As a result, two agricultural drains immediately north of Grand Bend, a storm sewer within the village and another tributary of the Ausable River were all shown to have contributed to the bacterial pollution of the beach water.

Results of the serological identifications of isolates from Ipperwash Provincial Park beach and Goderich Harbour beach were less informing as is shown in Table 11. It is possible that an insufficient number of isolates from the beach water were serotyped.

5.13.3 Survival Rate of Escherichia coli

In the third acitivity, the die-off/survival rate of the fecal coliform bacterium Escherichia coli was determined. Diffusion chambers were loaded with E. coli at approximately the concentration found in human feces. The resultant die-off rates, shown in Figures 26 to 28 were found to vary with concentrations of cells utilized in the chamber. At 10^9 cells per mL, a period of approximately 5 days was required to reach a concentration of 10^2 cells per mL. When the initial concentration exceeded 10^9 cells per mL, the die-off period increased by approximately 48 hours. Unfortunately, these experiments were not completed because of rough lake conditions.

5.14 Component 14. Bacterial Contamination of Beach Sediments

The sampling of sediments in the swimming areas at Ipperwash, Grand Bend and Goderich was conducted to determine the fecal coliform and fecal Streptococci concentrations. For comparison, water samples were also taken at the same sampling locations.

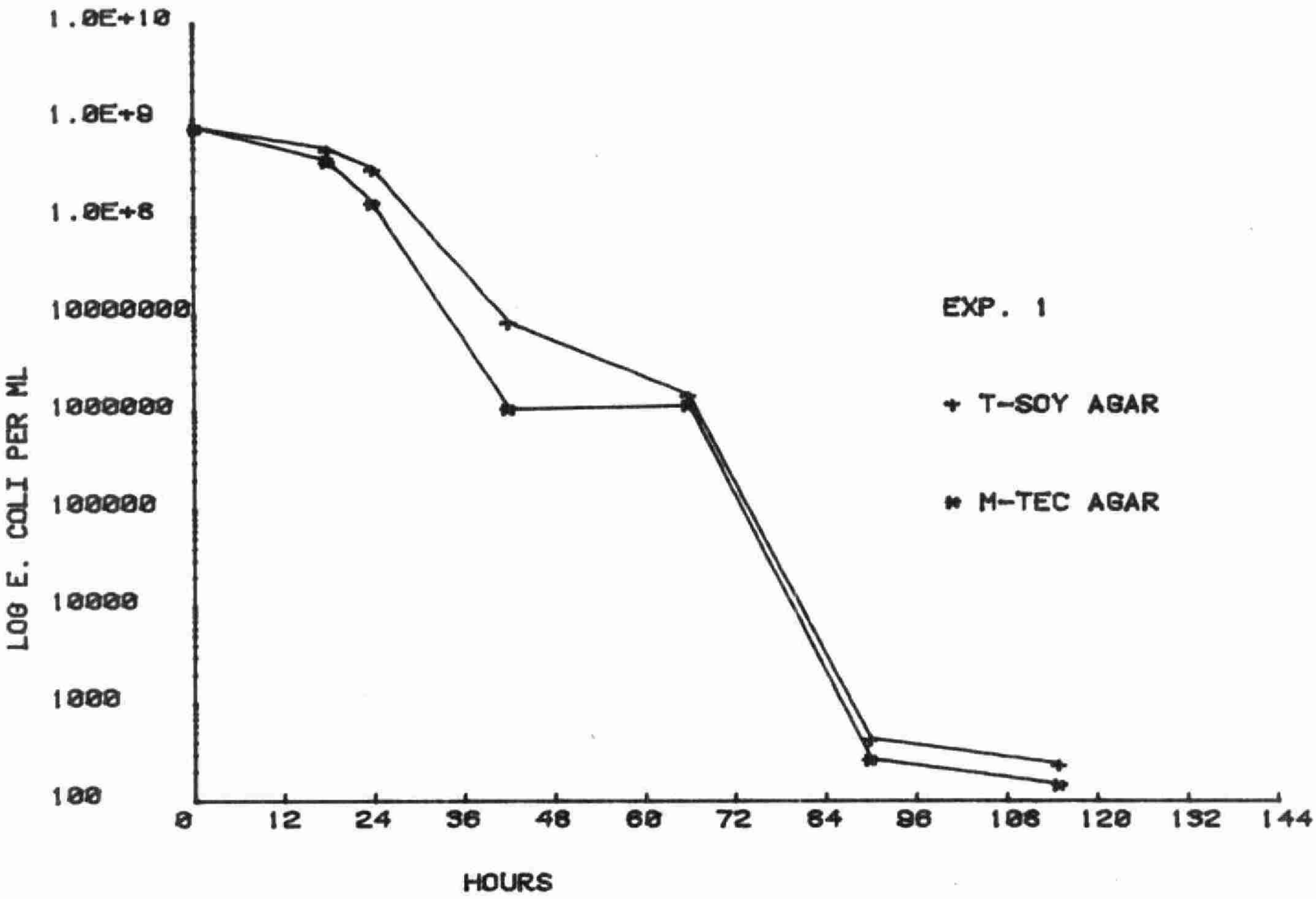


Figure 26. Levels of E. coli recovered on T-soy and m-Tec agar from diffusion chambers submerged in Lake Huron beach water.

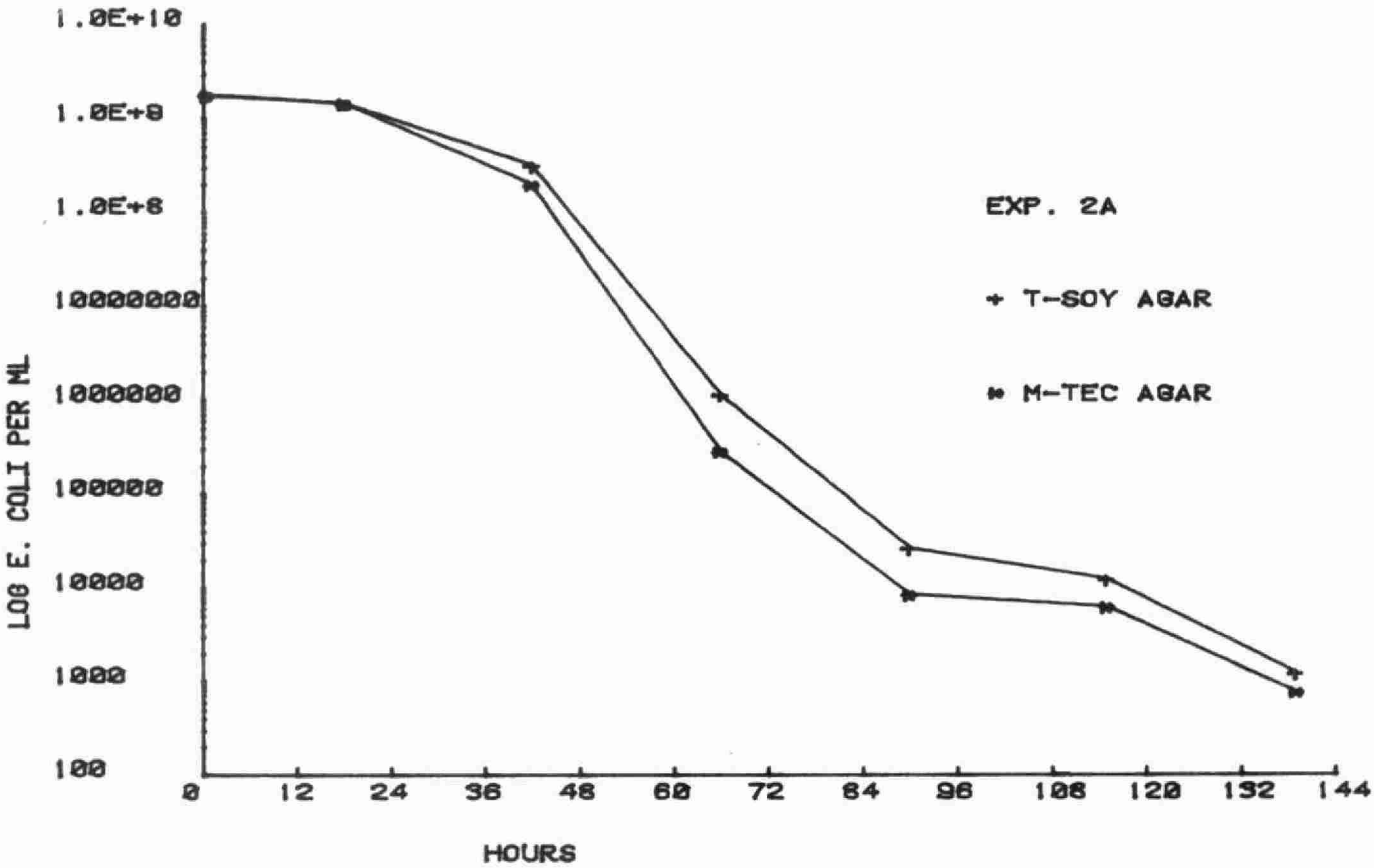


Figure 27. Levels of E. coli recovered on T-soy and m-Tec agars from Unit 1 diffusion chamber submerged in Lake Huron beach water.

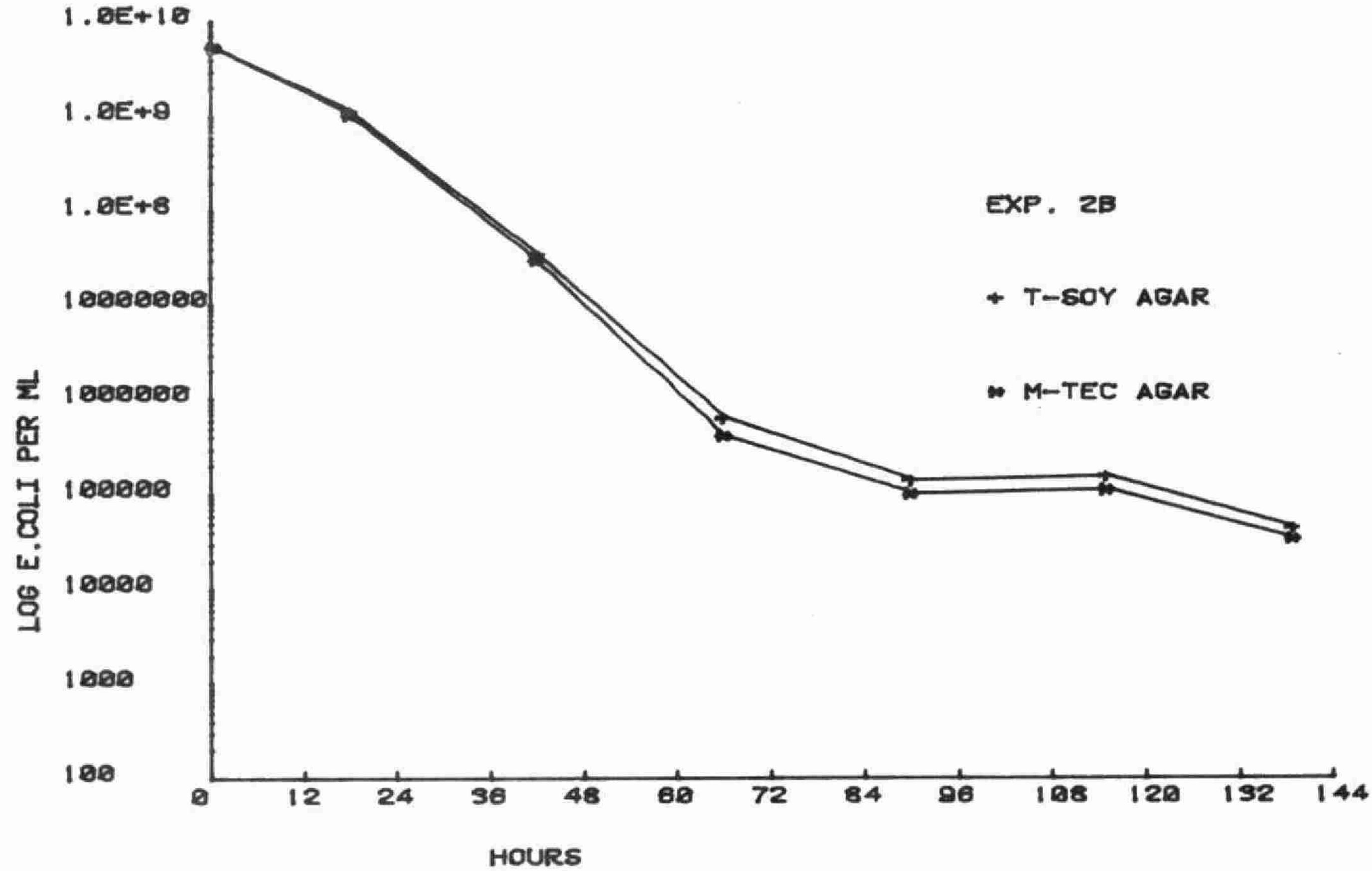


Figure 28. Levels of E. coli recovered on T-soy and m-Tec agars from Unit 2 diffusion chamber submerged in Lake Huron beach water.

Results in Table 12 show the levels of bacteria found in the sediment and the water at the ankle and waist depth sampling sites. It can be observed that the levels of fecal coliforms were, in general, higher in the sediments of Goderich Harbour beach than the other two study beaches as was the case for the bacterial levels in water. The water above the sediment sampling sites did not have as high fecal coliform and fecal Streptococci levels as did the sediment. Since the lake water was relatively calm on the day of sediment sampling, it was concluded that significant increases in fecal coliform and fecal Streptococci levels in the water could result from sediment re-suspension.

Of interest were the higher levels of fecal indicator bacteria in the sediment of Ipperwash Provincial Park beach than the Grand Bend beach. Although the sediments were higher in bacteria, the bacterial concentrations determined routinely in the water were generally lower at the Park beach than at Grand Bend. It is speculated that the fine sand of the Park beach sediment support higher concentrations of bacteria than the coarse sand of the Grand Bend beach. This is likely related to the difference in surface area available for adsorption by bacteria. The lower concentration of bacteria in the water at the Ipperwash Park beach suggests that resuspension of the sediments does not occur to the same extent as at Grand Bend. This is supported by the lower turbidity values observed in the Ipperwash Beach water. As mentioned earlier, the foreshore slope is gradual resulting in the waves breaking offshore also resulting in less re-suspension.

In an attempt to obtain samples of the floc-like material which lies at the sediment water interface, samples were taken at the Grand Bend beach using the vacuum sampling device. The sampling data displayed in Table 13 shows the levels of fecal indicator bacteria found in a suspension of this material. Although the levels of bacteria recovered are significant, they are considerably lower than the

Table 12. Concentration of fecal coliform and fecal Streptococci in sediment and water of the study beaches.

Location, Date		Sediment Bacterial Concentration, Depth of Water: Ankle FC	Ankle FS	Waist FC	Waist FS	Water Bacterial Concentrations, Depth of Water: Ankle FC	Ankle FS	Waist FC	Waist FS
		Numbers = bacteria per 100 g - sediment				Numbers = bacteria per 100 mL water			
Grand Bend	6.1.84			430	36			24	8
Ipperwash	6.1.84			36	36			8	20
Grand Bend	7.1.74			L300	L300			28	4
				920	360			48	20
				1,500	L300			64	20
Grand Bend	7.2.84			2,300	L300			16	8
				920	360			44	27
				740	L300			440	32
Grand Bend	7.20.84			3,200	L300			220	164
				24,000	310			270	196
				4,300	360			370	172
Grand Bend	7.21.84			9,300	L300			160	48
				360	360			110	36
				L300	L300			44	24
Grand Bend	7.31.84	L300	L300	360	L300	60	8	40	8
		360	L300	360	L300	184	28	160	24
		L300	L300	L300	L300	100	36	84	16
Ipperwash	7.31.84	2,300	360	L300	L300	4	8	L4	4
		2,300	360	1,500	360	28	8	12	4
		920	360	L300	L300	124	56	24	20
Goderich	7.31.84	9,300	360	24,000	L300			52	16
		46,000	360	4,300	L300			156	148
		920	360	L300	L300			72	16

L = less than
FC - fecal coliforms
FS - fecal Streptococci

Table 13. Bacterial concentrations in sediment-floc obtained with a vacuum sampler at the sediment-water interface.

Location, Date		Fecal Coliforms	Fecal Streptococci
		(Numbers of bacteria per 100 mL in sediment-floc)	
Grand Bend	8.15.84	230	L30
(beach)		92	36
(harbour)		36	L30
Grand Bend	9.11.84	L30	L30
(beach)		430	92
		36	L30
		230	L30
		92	L30
Grand Bend	12.11.84	43	9.2
(beach)		43	43
		93	43

bacterial concentrations found in the heavier bottom sediments. It is evident that this light material would be readily resuspended with moderate wave action.

The results obtained using an "inverted bottle" sampling technique indicated that bacterial levels associated with the floc-like material is substantial (Table 14).

As it was not possible to retrieve the floc-like material when obtaining sediment samples using a scoop, it is apparent that the bacterial concentrations detected were obviously an under-estimation of the bacterial levels in the sediment. This inaccuracy may be further magnified by the enumeration method used since recent reports suggest that the Most Probable Number technique used to enumerate the bacteria present in sediment may under-estimate bacterial concentrations by as much as 100 percent.

In conclusion, it was evident from the levels of fecal indicator bacteria in the sediment, that sediment resuspension contributes bacteria to the water column. In Table 15, it can be observed that 82% of the time when the lake condition became increasingly rough, the concentrations of bacteria in water increased. Conversely, 87% of the time when lake conditions decreased in roughness, bacterial concentrations decreased in the water. In Figure 29 the actual concentrations of fecal coliforms detected in the water are shown with respect to the lake condition at Goderich beach. It is evident that the fecal coliform levels were greatly elevated during rough lake conditions and most often lower during calm lake conditions.

Table 14. Concentrations of bacteria in the sediment - floc at the sediment water interface before and after suspended solids removal.

Location	Prefiltration Fecal Coliform Concentration	Prefiltration Fecal Strep Concentration	Post-filtration Fecal Coliform Concentration	Post-filtration Fecal Strep Concentration
	(Numbers - bacteria per 100 mL)			
Grand Bend	1200	200	20	L10
	820	260	110	110
	52	36	16	12
	48	32	24	8

Table 15: Comparison of change in lake roughness to change in fecal coliform concentration

GRAND BEND

	Increase in Fecal Coliforms	Decrease in Fecal Coliforms
INCREASE IN ROUGHNESS	10	1
DECREASE IN ROUGHNESS	0	9

IPPERWASH

	Increase in Fecal Coliforms	Decrease in Fecal Coliforms
INCREASE IN ROUGHNESS	3	2
DECREASE IN ROUGHNESS	1	7

GODERICH 1 & 2

	Increase in Fecal Coliforms	Decrease in Fecal Coliforms
INCREASE IN ROUGHNESS	5	1
DECREASE IN ROUGHNESS	1	6

GODERICH 3

	Increase in Fecal Coliforms	Decrease in Fecal Coliforms
INCREASE IN ROUGHNESS	5	1
DECREASE IN ROUGHNESS	2	5

SUMMARY

	Increase in Fecal Coliforms	Decrease in Fecal Coliforms
INCREASE IN ROUGHNESS	23/82	5/18
DECREASE IN ROUGHNESS	4/13	27/87

Number of Times

23/82

Percent of Time

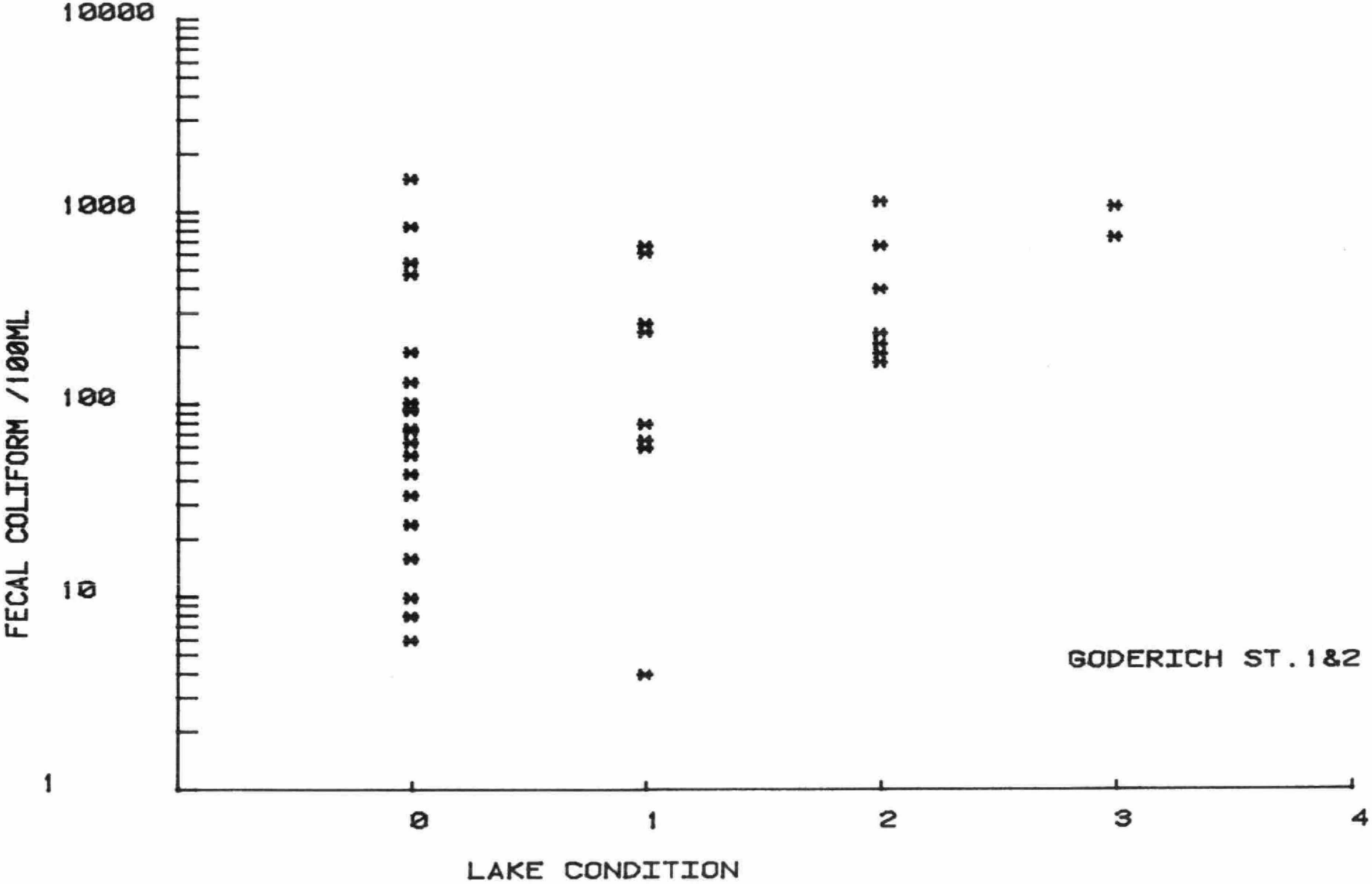


Figure 29. Fecal coliform concentrations as detected in the beach water of Goderich Harbour versus lake condition (0 clam, 1 fairly calm, 2 rough, 3 very rough)

	DATE DUE		
Aug 18/02			